

# Status of the widow rockfish resource in 2003

**Xi He, Stephen V. Ralston, Alec D. MacCall,  
Donald E. Pearson, and Edward J. Dick**

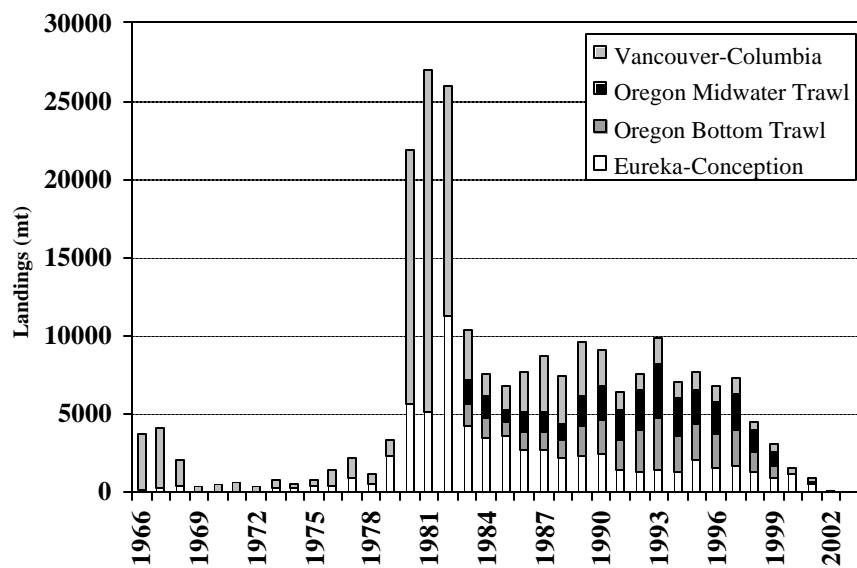
National Marine Fisheries Service  
Southwest Fisheries Science Center  
Santa Cruz Laboratory  
110 Shaffer Road  
Santa Cruz, CA 95060

(Draft submitted to the June 2003 Council Meeting)  
**May 2003**

## Executive Summary

Stock: This assessment applies to widow rockfish (*Sebastodes entomelas*) located in the territorial waters of the U.S., including the Vancouver, Columbia, Eureka, Monterey, and Conception areas designated by the International North Pacific Fishery Commission (INPFC). The stock is assumed to be a single mixed stock and subject to four major fisheries (see figure below).

Catches: The earliest records of foreign landings of widow rockfish were in 1966. U.S. catches of widow rockfish began in 1973 (117 mt), peaking in 1981 (26,938 mt, see figure below). Since the 1981 peak there has been a steady decline in the landings of widow rockfish to 1,794 in 2001 and to 263 mt in 2002 (2002 catch estimate may not be completed). Catches were mostly from commercial fisheries. Catches from recreational fisheries ranged from 3 mt in 2002 to 375 mt in 1982. The dominant gear type historically has been the midwater trawl. During the early 1990s, bottom trawl catches nearly matched the midwater trawl catches. Since the late 1990s, midwater trawl again became the dominant gear type.



Data and assessment: The last assessment of widow rockfish was conducted in 2000 using an age-based population model. All fishery data, including landings, age composition, and logbook catch rates, were recently downloaded from the PacFIN, CALCOM, and NORPAC databases, or provided by state agencies. The data sets were then re-analyzed and compared to the data compiled in the previous assessments. Unlike the previous assessments which used a general linear model to derive annual indices of CPUE, this assessment used a Delta-GLM (generalized linear model) method to derive indices. Like the last assessment, an age-based population model was used in this assessment, and the model was programmed in AD Model Builder (ADMB) (Williams et al. 2002). However, the ADMB code was substantially modified to allow more flexibility in data inputs, fishing fleet modification, and the ability to produce data files for further rebuilding analysis. Likelihood functions were also modified to formats similar to those used in the stock synthesis program. In addition, the Markov Chain Monte Carlo (MCMC)

simulation was enabled in the model, allowing approximation of the Bayesian posterior distributions for key parameters of interests.

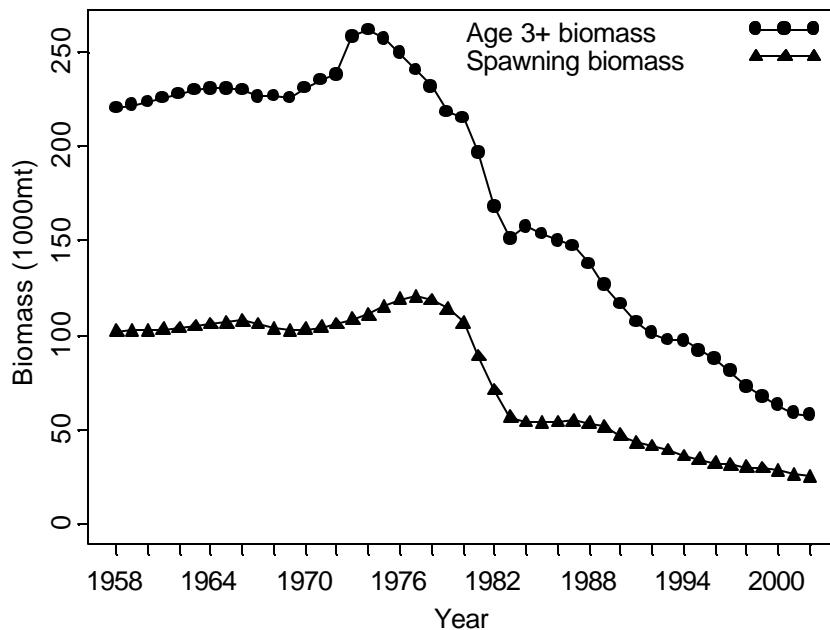
Unresolved problems and major uncertainties:

1. The primary source of information on trends in abundance of widow rockfish comes from the Oregon bottom trawl logbook data, which is a questionable source of information for widow rockfish. In addition, no information after 1999 in the Oregon bottom logbook trawl data can be used in the assessment because the catch rates were very low due to trip limits and other management regulations.
2. Natural mortality has been fixed at 0.15 based on previous assessments, but the validity of this estimate is uncertain.
3. The stock is arbitrarily defined from the USA-Canada border and south even though the species does exist in Canadian waters and a fishery developed since the mid-1980s. The current assessment assumes that the Canadian fishery has no influence on the resource in US waters. This assumption needs to be evaluated. If it is concluded that the catches in Canadian waters have no influence on the resource in US waters, the current approach can be continued. Otherwise, it may be necessary to do a joint assessment.
4. The 2002 juvenile index derived from the Santa Cruz laboratory midwater trawl survey is considerably higher than any other estimates since 1989. The index is derived from sampling in a relatively small geographical area compared to the expected distribution of the juveniles and the index is expected to be sensitive to changes in distribution and not only changes in juvenile abundance. If the 2002 year-class is as large as the index suggests, it could result in substantial stock increases. However, the relationship between the index and subsequent recruitment has been highly variable, and given the concerns about the reliability of the index, there remains considerable uncertainty about the size of the 2002 year-class.
5. The value of the power in the curvilinear relationship between the juvenile index and subsequent recruitment is a major source of uncertainty on current stock status and recent trends. This subject requires further research in order to identify reasons for the existence of such a curvilinear relationship and for reducing the range of possible values for the exponent.
6. Similar to other rockfish species in the area, the biomass of widow rockfish has decreased steadily since the early 1980s and recruitment during that period is estimated to have been considerably smaller than before the mid 1970s. The reason for the lower recruitment since the early 1980s could be due to lower spawning stock biomass, but it could also be due to a lower productivity regime. If recruitment is currently low because of hydro-climatically unproductive conditions, it may not be possible to rebuild to the target biomass until more productive conditions occur. If the conditions improve, rebuilding could be faster than expected.

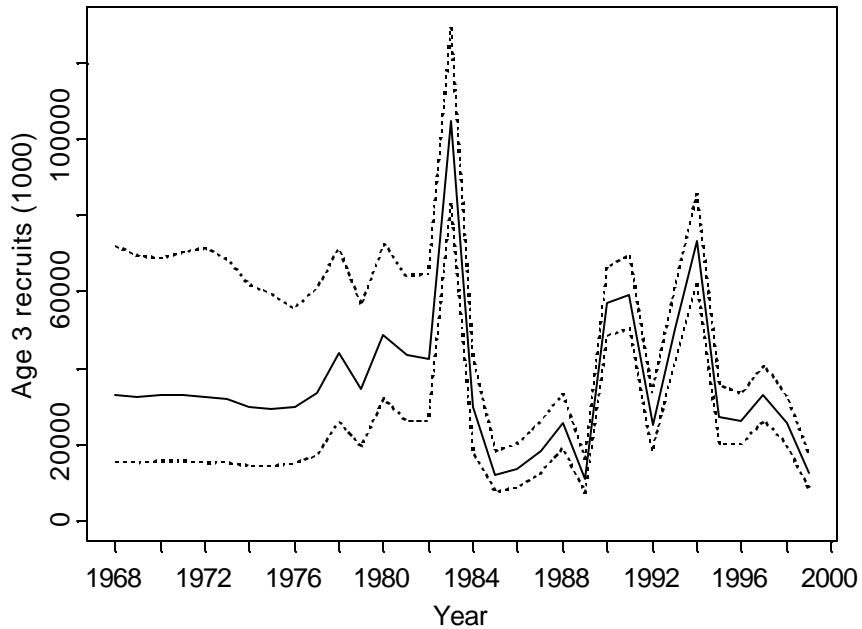
Reference points: The percentage ratio of spawning output in 2002 to unfished spawning output ( $B_0$ ) is the population status. A population status below 25% indicates an overfished stock, and the population statuses between 25% and 40% indicate a precautionary zone. A population status over 40% is a healthy stock.

Stock biomass: Stock biomass has shown a steady decline since 1974, soon after the fisheries for widow rockfish began. Spawning biomass peaked in 1977 and has shown a steady decline since then.

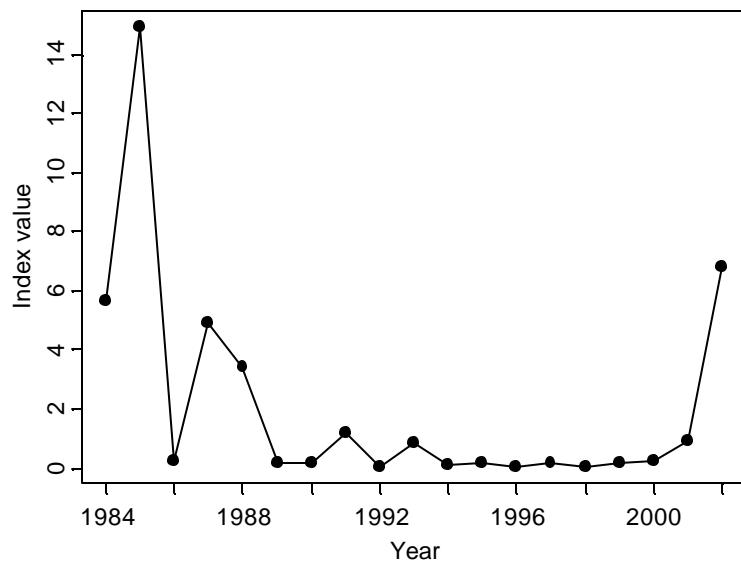
### Age 3+ biomass and spawning biomass



Recruitment: The model estimated time series of recruitment of age 3 fish from 1958 to 1999. It shows high variability in the early years of the time series, but in recent times has been less variable with a slight decreasing trend which seems to be following the decreasing trend in biomass.

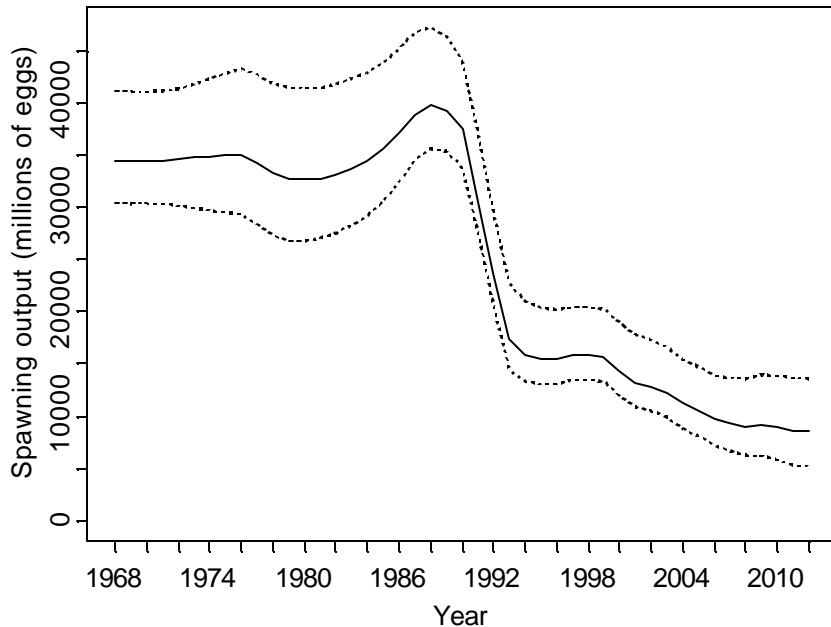


The most recent midwater juvenile survey by the Santa Cruz Laboratory, however, showed a great increase of age 0 fish abundance in 2002. This datum point has no influence in the current stock assessment, but could have large impacts on the rebuilding analysis. To include the information on this year-class in the future projections, the sizes of the recruitments for 2003-05 (i.e. the 2000-02 year-classes) are pre-specified in the rebuilding analysis rather than being generated by the stock-recruitment relationship (see the rebuilding analysis by He et al (2003) for details).



Exploitation status: The point estimate of the current spawning output (9,755), from the base-model run, is at 24.65% of the unfished level (39,567). The unfished spawning output ( $B_0$ ) is

defined as spawning output in 1958. The median estimate of the current spawning output over the unfished level, from a MCMC run, is at 24.82% with a 95% confidence interval of 15.68% and 35.55%, respectively.

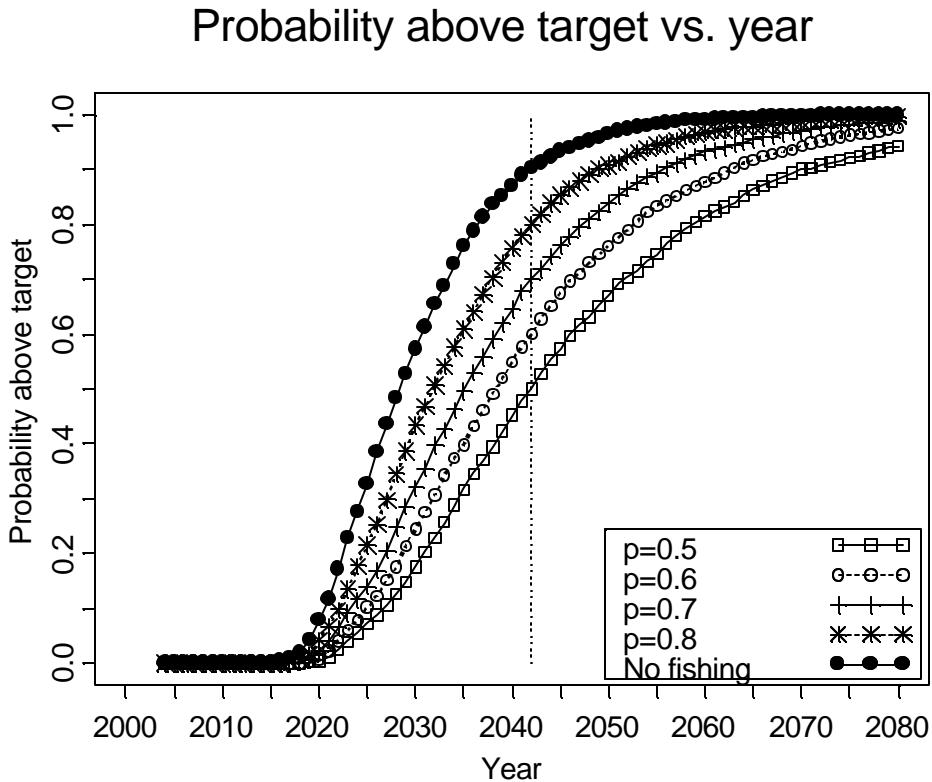


Management Performance: See below.

Year	Harvest Guideline	Allowable Biological Catch	Landings	Catch
1989	12100	12400	12479	14856
1990	12400	8900	10113	12039
1991	7000	7000	6290	7488
1992	7000	7000	6036	7186
1993	7000	7000	8190	9750
1994	6500	6500	6366	7579
1995	6500	7700	6952	8276
1996	6500	7700	6478	7712
1997	6500	7700	6989	8320
1998	5090	5750	4090	4869
1999	5090	5750	4450	5298
2000	5090	5750	3809	4535
2001	2300	3727	1794	2136
2002	856	3727	263	313
2003	832	3871	-	-

Forecasts: A forecast based on the base model from the stock assessment and one of rebuilding scenarios (Model 8) is presented below. The rebuilding scenarios were constructed from three

factors: (1) whether the recruitments (age 3) for 2003-05 were pre-specified; (2) whether a stock-recruitment relationship or recruits-per-spawner ratios were used to generate future recruitment; and (3) a range of the power coefficient for the midwater juvenile survey index. Model 8 uses the power coefficient from the stock assessment base model, and has recruitments pre-specified for 2003-05 and future recruitment after 2005 generated using recruits-per-spawner ratios. The figure below shows time-series of the probability of the spawning output of widow rockfish exceeding the target ( $0.4B_0$ ) for four rebuilding strategies and a scenario of no fishing. Legends of  $p=0.5$ ,  $p=0.6$ ,  $p=0.7$ , and  $p=0.8$  correspond to probabilities that the population will be rebuilt by a pre-specified year ( $T_{\max}$ ). The vertical line is  $T_{\text{target}} (=2042)$ , which is the year when the population recovers to the target level at a probability of 50%. The figure indicates that the population will have very small probability ( $\leq 7.9\%$ ) of recovering to the target before 2020 even without fishing, but should recover to the target by 2042 with at least 50% of probability. As expected, the probability is the highest ( $=90.2\%$ ) with no fishing, and the probability is the lowest ( $=50\%$ ) for  $p=0.5$ . The Optimum Yields (OY) for 2004 corresponding to  $p=0.5$ ,  $p=0.5$ ,  $p=0.7$ , and  $p=0.8$  are 354mt, 284mt, 212mt, and 123mt, respectively (see He et al (2003) rebuilding analysis for details).



Decision Table: This decision table (see below) is taken from a risk analysis of the rebuilding analysis (He et al. 2003). The risk analysis used four catch levels on three rebuilding models. These models use the outputs from the base model in the stock assessment but with assumptions about whether recruitment for 2003-5 should be pre-specified and how future recruitment should be generated. Model 5 has recruitments pre-specified for 2003-05 and future recruitment after 2005 generated using the stock recruitment relationship. Model 2 does not have recruitments

pre-specified but future recruitment generated using recruits-per-spawner ratios. Model 8 has recruitments pre-specified for 2003-05 and future recruitment after 2005 generated using recruits-per-spawner ratios. The numbers in bold-italic typeface indicate the basis for the first three catch levels. Abbreviations are: OY = Optimum Yield; RP = recruitment is pre-specified; SR = the stock-recruitment relationship is used to generate future recruitment; and NA = not applicable. Symbols are: OY = Optimum Yield for 2004; F = fishing mortality;  $P_{max}$  = probability (%) to rebuild by  $T_{max}$ ;  $T_{target}$  = year in which the probability of recovery is 0.5; and  $P_{100}$  = probability (%) of the spawning output being above the current spawning output in 100 years (year 2103).

Catch level (2004 OY (mt))		Model 5 (RP=N, SR=Y)	Model 2 (RP=N, SR=N)	Model 8 (RP=Y, SR=N)
35	OY	<b>35</b>	35	35
	F	<b>0.0012</b>	0.00115	0.00114
	$P_{max}$	<b>49.9</b>	80.4	87.8
	$T_{target}$	<b>2123</b>	2045	2028
	$P_{100}$	<b>91.2</b>	100.0	100.0
194	OY	195	<b>194</b>	194
	F	0.0064	<b>0.0064</b>	0.00634
	$P_{max}$	26.0	<b>60.1</b>	72.2
	$T_{target}$	NA	<b>2053</b>	2033
	$P_{100}$	75.4	<b>100.0</b>	100.0
284	OY	283	282	<b>284</b>
	F	0.0093	0.00925	<b>0.0093</b>
	$P_{max}$	14.9	46.7	<b>60.1</b>
	$T_{target}$	NA	2058	<b>2037</b>
	$P_{100}$	61.8	100.0	<b>100.0</b>
501	OY	502	499	501
	F	0.0165	0.0164	0.0165
	$P_{max}$	2.6	18.1	30.9
	$T_{target}$	NA	2081	2052
	$P_{100}$	27.1	99.6	100.0

Recommendations: Model 8 in the rebuilding analysis uses the base model from this assessment, uses pre-specified recruitments for 2003-05 based on the midwater juvenile survey index, and generates future recruitment by using recruits-per-spawner ratios. Recruits-per-spawner was used in the last assessment and in the last rebuilding analysis to generate future recruitment, and was also recommended by the 2003 STAR panel. Assuming the strong 2002 year-class will recruit to the fishery in 2005, and recruits-per-spawner ratios are proper ways of generating future recruitments, the recommended Optimum Yield (OY) for 2004 would be 284mt. Detailed descriptions on Model 8 and other rebuilding models are presented in He et al. (2003).

Sources of additional information: The California logbook index was examined in the 2000 assessment, and it was decided not to use the data because of concerns about different gear types going into the index calculations (Ralston 1999). Fishery data from Soviet Union vessels operating off the U.S. West Coast from 1970-78 were examined, but poor record keeping and

low catches in some years limited the utility of this data. Both data sets were not used in this assessment. Data from the Alaska Fisheries Science Center's triennial bottom trawl survey were not used in this assessment to derive abundance indices for widow rockfish because the survey gear is not designed to catch widow rockfish and the previous assessment (Williams et al. 2000) showed no utility of the data series. However, the STAR Panel has recommended that the triennial trawl survey be analyzed further and be considered for inclusion in the future assessment.

## Introduction

Widow rockfish (*Sebastodes entomelas*) is an important commercial groundfish species belonging to the scorpionfish family (Scorpaenidae). It ranges from southeastern Alaska to northern Baja California, where it frequents rocky banks at depths of 25-370m (Eschmeyer et al. 1983, Wilkins 1986). In those habitats it feeds on small pelagic crustaceans and fishes, including especially *Sergentes similis*, myctophids, and euphausiids (Adams 1987). There is no evidence that separate genetic stocks of widow rockfish occur along the Pacific coast and the species has been treated as one stock with four separate fisheries (Hightower and Lenarz 1990; Rogers and Lenarz 1993; Ralston and Pearson 1997, Williams et al. 2002).

A midwater trawl fishery for widow rockfish developed rapidly in the late 1970's and increased rapidly in 1980-82 (Gunderson 1984, Fig. 1 and Table 1). Large concentrations of widow rockfish had evidently gone undetected because aggregations of this species form at night and disperse at dawn, an atypical pattern for rockfish. Since the fishery first developed, substantial landings of widow rockfish have been made in all three west coast states.

Management of the fishery began in 1982 when 75,000 lbs trip limits were introduced in an effort to curb the rapid expansion of the fishery (Tables 2-3). These were reduced to 30,000 lbs in 1983 and the fishery was managed by alteration of trip limits within the fishing season. A 10,500 mt/yr Allowable Biological Catch (ABC) for widow rockfish was instituted in 1983 (Table 3), but no harvest guideline was established. This form of management continued with alterations in ABC and trip limits until 1989 when a 12,100 mt/yr harvest guideline was implemented (Tables 2-3). From 1994-1997 the harvest guideline was changed to 6,500 mt and then reduced to 5090 mt/yr for 1998 to 2000. Based on the 2000 stock assessment and the rebuilding analysis of 2001, the harvest guidelines were further reduced to 2,300 mt for 2001, 856 mt for 2002 and then to 832 mt for 2003.

This assessment used an age-based population model similar to those used in previous assessments (Ralston and Pearson 1997, Williams et al. 2000). All data were recently downloaded from the PacFIN, CALCOM, and NORPAC databases, or provided by state agencies. The data sets were then re-analyzed and compared to the data compiled in the previous assessments. Unlike the previous assessments which used general linear model to derive annual indices of CPUE, this assessment used a Delta-GLM (generalized linear model) approach to derive indices. Like the last assessment, an age-based population model was used in this assessment, and the model was programmed in AD Model Builder (ADMB) (Williams et al. 2002). However, the ADMB code was substantially modified to allow more flexibility in data inputs, fishing fleet modification, and the ability to produce data files for further rebuilding analysis. Likelihood functions were also modified to formats similar to those used the stock synthesis program. In addition, the Markov Chain Monte Carlo (MCMC) simulation was enabled in the model, allowing approximation of the Bayesian posterior distributions for key parameters of interests.

## Data

### Biological information

Growth in length for widow rockfish has been described using von Bertalanffy growth equations in two papers by Lenarz (1987) and Pearson and Hightower (1991). In their analyses

it was determined that females attain a larger size compared to males and fish from the northern part of the range tend to be larger at age compared to those in the south. For these reasons we chose to use the sex specific and area specific estimates for length-at-age. Furthermore, we chose to use the estimates listed in Pearson and Hightower (1991), shown below and in Figure 2, because they are from a more recent and comprehensive analysis of widow rockfish growth compared to the analysis by Lenarz (1987). In order to match the fisheries, we used the Columbia-Eureka INPFC area border ( $43^{\circ}$  Lat.) to delineate north from south.

Parameter	Females (north)	Males (north)	Females (south)	Males (south)
$L_{\text{inf}}$ (cm)	50.54	44.0	47.55	41.5
$K$	0.14	0.18	0.2	0.25
$t_0$	-2.68	-2.81	-0.17	-0.28

Sex specific weight-at-age estimates were computed using the length-at-age estimates above with sex specific length-weight regressions for widow rockfish developed by Barss and Echeverria (1987) (Figure 2). The length-weight regression equation is  $W = aL^b$ , where  $W$  is the weight (g) and  $L$  is the length (cm). The sex specific parameter values used in this assessment are listed below:

Parameter	Females	Males
$a$	0.00545	0.01188
$b$	3.28781	3.06631

Estimates of maturity and fecundity of female widow rockfish were obtained from Barss and Echeverria (1987) and Boehlert et al. (1982), respectively. Age specific maturity estimates were taken directly from the literature instead of fitting a parametric model (Figure 3), while age specific fecundity was computed using the weight-fecundity regression:

$$F = 605.71^W - 261830.7 \quad (1)$$

where  $F$  is fecundity (# eggs) and  $W$  is weight (g). The weight-fecundity regression applied to the southern weight-at-age estimates resulted in negative values for ages 3 and 4. The weight-fecundity regression developed by Boehlert et al. (1982) was based on fish captured from Oregon and apparently does not apply to widow rockfish in the south. The maturity estimates shown in Figure 3 indicate a substantial difference in maturity-at-age between the north and south, with the northern fish maturing at an older age. Lacking any other estimate of fecundity for the south, we applied the weight-fecundity regression from the north and modified the estimates for ages 3-5 to approximate an asymptote to 0 (Figure 3).

## Landings

All landings for the period 1966-2002 were summarized into four areas (fisheries): (1) Vancouver-Columbia (VC); (2) Oregon mid-water trawl (ORMWT); (3) Oregon bottom trawl (ORBTWL); and (4) Eureka, Monterey, and Conception (EMC). Landings statistics used in this assessment were derived from four sources. First, all commercial landings from 1980 were extracted from the PacFIN database. Second, the very small annual recreational take of widow rockfish was extracted from the Marine Recreational Fishing Statistics Survey (MRFSS)

database. Third, all landings from 1966 to 1972, and some landings from 1973 to 1976 were directly taken from a summary table in Rogers (2003), who recently compiled summaries of foreign catches in the period. Fourth, some landing from 1973 to 1976 and all landings from 1977 to 1979 were directly copied from the last assessment (Williams et al. 2000). Summarized landings by year are presented in Table 1 and Figure 1.

As in the last assessments of widow rockfish, the data were pooled over states into INPFC area blocks. These in turn were collapsed into northern and southern areas, representing the U.S. Vancouver and Columbia areas (VC, ORMWT, and ORBTWL) and the Eureka, Monterey, and Conception areas (EMC), respectively. The northern and southern areas are conveniently delineated by the 43° latitude line. Within the southern area, widow rockfish landings were further condensed by summing over gears (i.e., trawl, other commercial, and recreational), providing annual estimates of landings from the southern area fishery. In the northern area, however, landings were partitioned into three separate fisheries; the Oregon midwater trawl fishery, the Oregon bottom trawl fishery, and the remaining catch of widow rockfish, referred to as the Vancouver-Columbia fishery. Because identification of gear types in Oregon (midwater or bottom trawl) did not begin until 1983, all landings in the northern area prior to that time were assigned to the Vancouver-Columbia “trawl” fishery.

It should be noted that there are some small discrepancies in the landing statistics between those recently extracted from the PacFIN data and those used in the last assessment. Overall, these discrepancies are very small and insignificant, except for the Eureka, Monterey, and Conception area in 1981 and 1983, the new estimates were 1199mt (19%) and 2266mt (35%) less than those in the old estimates, respectively. These discrepancies were probably due to new expansion methods used to compile landing statistics.

#### Age composition data

Widow rockfish otolith samples collected coastwide since 1989 have been aged at the Santa Cruz (Tiburon) Laboratory using the break and burn aging method (Pearson and Hightower 1991). Prior to 1989, the ages of all Vancouver-Columbia fish were obtained by researchers in the State of Washington, who used surface readings. Prior to 1987, Oregon widow rockfish were aged by investigators in Oregon, who used the break and burn aging method. All California fish were aged by Santa Cruz Laboratory personnel using the break and burn aging technique.

Age validation of widow rockfish was conducted by marginal increment analysis (Lenarz 1987). Hyaline-zone formation, the measure of annual growth, appears to occur between December and April (Pearson 1996). For convenience all widow rockfish are assumed to be born on January 1. Variation in the timing of the hyaline-zone formation occurs between fish from Washington and California, which could affect age determination. Knowledge of the timing variation can be used to avoid mis-ageing and ultimately the variation in hyaline-zone formation is not likely to result in major age discrepancies (Pearson 1996).

Washington provided ageing data from samples collected during commercial market sampling. The data were then expanded using relative catches from US Vancouver and Columbia areas. Oregon provided raw sample data which were expanded using methods described in Sampson and Crone (1997). California age data was extracted and expanded from the CALCOM database (Pearson and Erwin 1997). Summaries of the numbers of fish aged and the number of trips sampled by year were also obtained. The sex specific age composition data

and sample size information for the four fisheries is presented in Tables 4-8 and Figures 4-7. As recommended by the STAR Panel, comparisons of age composition data between the previous assessment (Williams et al. 2000) and this assessment are also presented (Figures 8-11).

### Midwater trawl pelagic juvenile survey

Every year since 1983 the Groundfish Analysis Branch at the Southwest Fisheries Science Center's Santa Cruz/Tiburon Laboratory has conducted a midwater trawl survey, which is designed to assess the reproductive success of a group of rockfishes, including widow rockfish. The survey is conducted during May-June, the time of year when the pelagic juvenile stage is most susceptible to capture. Studies have shown that abundance statistics summarized from the survey gauge impending recruitment (Adams 1995; Ralston and Howard 1995; Ralston et al. 1996).

The survey index is calculated after the raw catch data are adjusted to a common age of 100-day to account for interannual differences in age structure. The abundance data are gathered during three consecutive sweeps of a series of 36 fixed stations that are arrayed over 7 spatial strata that extend from Carmel ( $36^{\circ}30'N$ ) to Bodega ( $38^{\circ}20'N$ ). The final index is calculated using Delta-GLM (Generalized Linear Model) method with lognormal error structure (Pennington 1986, 1996, Stefansson 1996):

$$\log(\text{density}) = \mathbf{m} + Y_i + L_k + \mathbf{e}_{ijkl} \quad (2)$$

where  $u$  is the average  $\log(\text{density})$ ,  $Y_i$  is a year effect,  $L_k$  is a spatial effect, and  $\mathbf{e}_{ijkl}$  is a normal error term with mean zero and variance  $s_e^2$ . The back-transformed year-specific index, with bias-correction, was then calculated as:

$$\text{Index}_i = \exp\left(\mathbf{m} + Y_i + \bar{L} + \frac{s_e^2}{2}\right) p_i \quad (3)$$

where  $\bar{L}$  is mean effect of spatial unit, and  $p_i$  is binomial coefficient (proportion of positive CPUE in year  $i$ ):

$$p_i = \frac{\exp(\mathbf{m} + y_i + \bar{L})}{1 + \exp(\mathbf{m} + y_i + \bar{L})} \quad (4)$$

where  $\mathbf{m}$  is the average,  $y$  is year effect, and  $\bar{L}$  is average spatial effect. Coefficient of variance (CV) for each index value was computed from the jack-knife method.

Data from 1983 were deleted from the analysis because of small number of datum points. Because no juvenile widow rockfish were caught in 1992, 1994, and 1996, index values for those years were set to one half of the historical low value, and CVs for those years were set to a high value of 2.0. The resulting indices were entered into the model as relative indices of one year juvenile abundance (Table 9 and Figure 12). The index time series (1984-2002) was then shifted forward three years (1986-2005) to represent the abundance of age-3 widow rockfish, the age of recruitment in the assessment model.

### Oregon bottom trawl logbook

Oregon logbook data from 1984 to 1986 were provided by the Oregon Department of Fish and Wildlife, and data from 1987 to 2002 were extracted from the PacFIN database. Catch

per unit effort (CPUE) was computed as pounds of fish caught per hour trawled. The data were filtered before the analysis. Only records meeting the following criteria were used in the analysis: (1) the fishing gear code corresponded to bottom trawl or roller gear, (2) hauls were conducted during the months of January, February, or March, and (3) the location of the reported haul fell in the range of 42°30'N to 46°30'N latitude and 124°36'W to 124°54'W longitude. In addition, records associated with any vessel code or spatial unit that had less than 1000 pounds of widow catch over the entire period (1984 to 2002) were also deleted. Data from 2000 to 2002 were not used in the analysis because widow catches in those three years were very low due to trip limits and other management regulations (Tables 2 and 3).

Annual CPUE indices were derived using Delta-GLM (Generalized Linear Model) method similar to that used for deriving midwater trawl pelagic juvenile survey (see previous section), with an additional factor (vessel) included:

$$\log(CPUE) = \mathbf{m} + Y_i + V_j + L_k + \mathbf{e}_{ijkl} \quad (5)$$

where  $u$  is the average  $\log(CPUE)$ ,  $Y_i$  is a year effect,  $V_j$  is a vessel effect,  $L_k$  is a spatial (latitude and longitude) effect, and  $\mathbf{e}_{ijkl}$  is a normal error term with mean zero and variance  $s_e^2$ . The back-transformed year-specific CPUE, with bias-correction, was then calculated as:

$$CPUE_i = \exp\left(\mathbf{m} + Y_i + \bar{V} + \bar{L} + \frac{s_e^2}{2}\right) p_i \quad (6)$$

where  $\bar{V}$  and  $\bar{L}$  are mean effects of vessel and spatial unit, respectively, and  $p_i$  is binomial coefficient:

$$p_i = \frac{\exp(\mathbf{m} + y_i + \bar{V} + \bar{L})}{1 + \exp(\mathbf{m} + y_i + \bar{V} + \bar{L})} \quad (7)$$

where  $\mathbf{m}$  is the average,  $y_i$  is year effect,  $\bar{V}$  is average vessel effect, and  $\bar{L}$  is average spatial effect. Derived annual CPUE indices are presented in Table 10 and Figure 13.

### Pacific whiting bycatch indices

As in the previous assessments (Rogers and Lenarz 1993, Ralston and Pearson 1997, Williams et al. 2002), CPUE indices were computed that measured the incidental catch rate of widow rockfish in the at-sea pacific whiting fishery. Data from the foreign fishery, joint-venture fishery and recent domestic fishery were extracted from the whiting observer databases and were extracted from the NORPAC database.

Full descriptions on how the CPUE indices were derived are in Appendix A. Similar Delta-GLM approaches as used for the Oregon bottom trawl logbook were used in the analysis. Annual CPUE indices for the foreign fishery, joint-venture fishery, and domestic fisheries are presented in Table 11 and Figure 14. As recommended by the STAR Panel, annual CPUE indices from the domestic fishery after 1999 were excluded from the analysis because changes in management measures are expected to have more influence on the CPUE than changes in stock size.

### **History of modeling approaches**

Previous assessments for widow rockfish have been performed in 1989, 1990, 1993, 1997, and 2000 (Hightower and Lenarz 1989, 1990; Rogers and Lenarz 1993; Ralston and Pearson 1997, Williams et al 2000). In 1989 the assessment involved the use of cohort analysis and the stock synthesis program (Methot 1998). In 1993 and 1997, the age-based version of the stock synthesis program was used to assess the status of widow rockfish. In 2000, the assessment of widow rockfish utilized AD Model Builder (ADMB) software (Otter Research, Ltd. 2001), and applied an age-based analysis of the population with methods very similar to those used in the stock synthesis program. The differences between the ADMB model and stock synthesis are minor. The ADMB model estimates landings with a very low coefficient of variation (0.05), while stock synthesis treats landings in a slightly different manner and the initial age composition estimation process is slightly different in the two models. A full description of the ADMB model follows and should clarify any further differences between this model and the stock synthesis program used in past assessments of widow rockfish.

This assessment used the same modeling approach as in 2002. The ADMB code however was substantially modified to allow more flexibility in data inputs, fishing fleet modification, and outputs of data for further rebuilding analysis. Likelihood functions were also modified to formats similar to those used the stock synthesis program. In addition, the Markov Chain Monte Carlo (MCMC) simulation was enabled in the model, allowing approximation of the Bayesian posterior distributions for key parameters of interests.

## Model description

### General

This assessment uses an age-structured population model similar to the one used in the stock synthesis program (Methot 1998). Full descriptions of the population dynamics, catch equations, and associated likelihood functions are given in Appendix B. The model is written in a C++ software language extension, AD Model Builder (ADMB) (Otter Research, Ltd. 2001), which utilizes automatic differentiation programming (Griewank and Corliss 1991; Fournier 1996). The ADMB software allows for more rapid and accurate computation of derivative calculations used in the quasi-Newton optimization routine (Chong and Zak 1996). Further advantages of this software include the ability to estimate the variance-covariance matrix for all dependent and independent parameters of interest, likelihood profiling, and a Markov chain-Monte Carlo re-sampling algorithm for probability distribution determination. The ADMB model code and data files are listed in Appendix C and D, respectively.

The population model begins in 1958 and tracks numbers and catches of male and female widow rockfish in age classes 3-20 (age 20 is an age plus group). In the 2000 assessment, a starting year of 1968 was chosen based on the assumption that the 1965 year class was the earliest recruitment which could be reasonably estimated given a starting year of 1980 for the age composition information. In this assessment, the starting year was extended backward to 1958 because the new landing data from 1966 to 1972 were added. Recruitment estimates prior to 1958 are assumed equal to the 1958 estimate in the model, so that the model is estimating recruitment at age 3 for the years 1958-1999.

The data used in this model include 4 fishery catch-at-age compositions (sum across sexes equal to one), landings in weight for each fishery, NMFS Santa Cruz Laboratory midwater juvenile survey index, Oregon bottom trawl logbook CPUE, and three whiting bycatch indices.

Fishing mortality in each year is scaled to the fishery landings assuming a coefficient of variation of 5%. Double logistic selectivity functions by age were estimated for each fishery.

### Natural mortality

Natural mortality ( $M$ ) is assumed to be constant for all ages and in all years. The initial model allowed the model to estimate a slightly higher natural mortality for males than females based on the observation that there were more old females than males in the age data. The model was presented to the STAR Panel. It was noted that greater proportions of males at younger ages could be due to differences in selectivity by gender. Allowing for different natural mortality had little impact on model results and the differences in  $M$  were small (<0.01). The STAR Panel considered that until the reason for the difference in age composition has been elucidated, the same natural mortality value should be used for both sexes. Therefore, natural mortality has been fixed at 0.15.

### Age compositions

The age data are modeled as multinomial random variables, with the year-specific sample sizes set equal to the number of samples collected, rather than the number of fish, which often overstates the confidence of the data (Table 8) (Quinn and Deriso 1999).

### Ageing error

The only information available for determination of ageing error was based on two point estimates of percent ageing agreement from the last two assessments (Rogers and Lenarz 1993; Ralston and Pearson 1997). From the previous assessments an estimate of 75% agreement for age 5 fish and 66% agreement for age 20 fish was modeled by assuming a linear relationship of percent agreement with age. These estimates of percent agreement at age were then fit to a set of age-specific normal distributions, which approximated the level of ageing agreement. The resulting matrix of true age versus reader age was then placed in the model

$$A_t = EA_r, \quad (8)$$

where  $A_t$  and  $A_r$  are  $n \times n$  matrices for true age and reader age, respectively,  $n$  is number of age classes, and  $E$  is a  $n \times n$  matrix for ageing error with the sum across each column equals to one.

### Landings

A constant CV of 0.05 is assumed for landing estimates. Year-specific fishing mortalities are computed for each fishery for those years in which there are landings estimates available. Fishing mortalities were zero from 1958 to 1965 since there are no landings estimates for those years.

### Fraction of landings in the north

Since there are area specific (north and south) estimates for weight-at-age and maturity, it is necessary to determine the fraction of the population to which each of these area-specific estimates apply. We used the sum of the domestic landings in the Vancouver-Columbia and both

Oregon trawl fisheries relative to the total landings as an estimate of the proportion of the population to which the northern weight-at-age and maturity functions could be applied. Foreign landings from 1966 to 1976 from Rogers (2003) were not used in computing the fractions. The annual change in this fraction seemed highly variable and not likely to be indicative of true declines in area abundances. For this reason, the time series of proportions of landings in the north were smoothed using a 7-year moving average (Figure 15). The results from the moving average were then put directly into the model, applying the 1973 value to the earlier years.

### Discards

The level of discards of widow rockfish is virtually unknown in most of years. Age compositions in discards and landings can be very different (typically small fish being discarded) and can be important in determining discard rates (Williams et al. 1999). In past assessments a value of 6% of total weight was assumed for years 1973-1982 and 16% of total weight for the years 1983-1999 (Hightower and Lenarz 1990). In this assessment, a value of 6% was also applied for years 1966 to 1972. The 16% estimate of discards is based on a dated study by Pikitch et al. (1988), which indicated most of the discards of widow rockfish were induced by regulations. The earlier 6% estimated is based on an ad hoc adjustment of the 16% by previous assessment authors (Hightower and Lenarz 1990). The 16% assumed value has likely become more uncertain in recent years due changes in regulations. For example, the most recent estimate on discard rate from the 2002 observer data, based on 89mt of widow rockfish catch, was 0.1%, which is much lower than the 16% assumed value.

### Midwater juvenile trawl survey

The Santa Cruz Laboratory midwater trawl juvenile survey is scaled to represent an index of 100 day-old larvae. For inclusion in the model the time series was lagged to correspond with the appropriate year class. Within the model a catchability coefficient is estimated and a power coefficient is fixed for the midwater trawl survey. The power transformation is included to account for possible density dependent mortality occurring between 100 days of age and age 3 (the age of recruitment in the model), which likely results in higher variance levels in the survey time series relative to age 3 recruitment time series.

### Logbook and bycatch indices

The Oregon bottom trawl logbook indices and whiting bycatch indices are treated as biomass indices and are estimated in the model with a catchability parameter for each index. The model has been equipped for the possibility of a power transformation of the indices, but in this case all the time series will be treated with a power of 1.0.

### Likelihood component weighting

There are eight likelihood components in the model (Appendix B): age-composition data, landings, recruitment residuals, midwater juvenile trawl survey index and four CPUE indices. Weighting in this assessment model has two levels (Appendix B). First, contribution of each datum point to its likelihood component is weighted by a fixed CV associated with the datum

point. Details on how a fixed CV is determined for each component are discussed later. Second, a weighting factor ( $I$ ) is assumed for each likelihood component and the final likelihood value for each component is multiplied by its weighting factor (Appendix B). In this assessment model, all weighting factor ( $I$ ) have been set to 1, except for the recruitment residual component and the midwater juvenile survey index component, whose weighting factors are set to be 0.5.

## Model selection and evaluation

Initial model runs were performed with all auxiliary data included. The relative importance of each data set was examined through an ordinary cross-validation analysis technique, whereby auxiliary components are de-emphasized one at a time and the results compared to each other. This technique allows determination of the contribution of each data source to the overall model fit, as well as to other components in the model. Table 12 shows the results of the cross-validation analysis. It appears that three whiting bycatch indices are less informative than other data sets.

A previous assessment (Williams et al. 2000) evaluated the utility of the midwater juvenile survey index by examining the recruitment estimates from the model run with the midwater trawl likelihood component de-emphasized. It used a power transformation to match the CV of the index to the CV of the recruitment estimates from the model for the time period of overlap. The results indicated a significant correlation ( $P < 0.05$ ) between the recruitment estimates from the model with the midwater trawl component de-emphasized and the power transformed index values (Figure 13 in Williams et al. 2000). It concluded that the midwater juvenile survey was a useful time series of recruitment indicator to be included in the model (see also Ralston et al. 1998, MacCall et al. 1999, and Done et al. 1999). The initial runs of this assessment also allowed the model to estimate the power coefficient (estimated values were about 10). The STAR review suggested the power coefficient to be fixed at 3.0 so that the magnitude of the variability in the survey index would roughly equal to the variability in the recruitment.

A previous assessment (Williams et al. 2000) also evaluated different selectivity functions in relations to the model fits to the data and results. The selectivity functions evaluated included single logistic, double logistic and lognormal functions. Year-specific (time varying) and sex-specific selectivity functions were also evaluated. The evaluation showed the most suitable selectivity function to be combined sex, double logistic selectivity functions with time varying ascending inflection points for the north (Vancouver-Columbia and Oregon trawl fisheries) and south (Eureka-Conception fishery) fisheries. Initially, the same selectivity configuration was used in this assessment. The STAR review later recommended that a non-time-varying selectivity be used. Thus, one selectivity function was used in this assessment.

Initial models used CVs estimated from the data in the likelihood functions. During the STAR Panel review, a constant CV (=0.5) was applied to all CPUE indices. The corresponding root mean square errors (RMSE) were then applied to likelihood functions of all CPUE indices. A CV of 0.5 was also applied to the likelihood function for the recruitment residuals ( $s_R = 0.5$ ).

The base model was tested repeatedly for its parameter estimation, properties of Hessian matrix, and convergence status. The final parameter estimation had a convergence criteria of  $10^{-8}$ , and positive definite Hessian and Cheloski matrices, which are required for successful Markov Chain Monte Carlo (MCMC) simulations. The convergence properties of the model

were also tested by running the model 500 times, in which initial values of each parameter were randomly perturbed by 50% of the best fitted value in the base model. Frequency distributions of negative log-likelihood values and the corresponding 2002 status of the population were plotted in Figure 16. Out of 500 runs, 488 of them resulted in proper fits. Although there were some local minima (Fig. 16) in parameter space, 95.9% (473 runs out of 488) of runs converged in the same results as the base model.

### Base run results

Results of the base model run are presented in Tables 13-16 and Figures 17-30. Parameter estimates and quadratic-normal approximation standard deviations are shown in Table 13. The resulting time series of total biomass, spawning biomass, spawning output, recruitment, and fishing mortality are presented in Table 14 and Figures 17-20. The fishery-specific selectivity curves are shown in Figure 21. The stock-recruitment relationship is shown in Figure 22. The fits to the landings are shown in Figures 23-24, and the fits to the various indices are shown in Figures 25-29. The fits of the age composition data are shown in Figure 30.

### Uncertainty and sensitivity analysis

A sensitivity analysis of the base model was run on different values for natural mortality, ranging from 0.09 to 0.21 (Table 17). The model fitted poorly for natural mortalities  $\geq 0.17$ , indicated by decreases of total likelihood value of more than 5 units. Although the model fitted well for natural mortalities  $\leq 0.09$ , it resulted in seemingly high value of the steepness ( $h \geq 0.379$ ). The model fitted well for natural mortalities of 0.13 and 0.15. The model results, in terms of the population statuses, from both mortalities were very similar (Table 17).

As recommended by the STAR Panel, a sensitivity analysis of the base model was also run on different power coefficients from 1.0 to 5.0 (Table 18). The results show that the lower power coefficients, the lower the spawning outputs in 2002.

A retrospective analysis was performed through a series of the model fits to the data with the most recent data removed. In this exercise, the model was run up to 1997, 1999, 2001, and 2002, respectively (Figure 31). The results indicate that the model is stable as the overall trends in spawning outputs were similar. However, the model only run to 1997 shows low spawning outputs in 1997, indicating that the last few years of data have some influence on previous years estimates.

### Rebuilding parameters

Unfished spawning output ( $B_0=39,567$ ) was calculated from the first year (1958) spawning output. The value is slightly lower than that computed from the average recruitment in the year 1958 to 1979 multiplied by spawning output per recruit (SPR=1.036,  $B_0=42,601$ ). Difference between two values is very small and both values are well within the 95% confidence intervals (30,148 and 52,597) determined by the likelihood profile run on  $B_0$ . The former was used in this stock assessment because it did not depend on how many pre-fishing years should be included in calculating  $B_0$ . Mean generation time was 16 years. A separated C++ program was written (embedded in the ADMB program) to produce a data file (“rebuild.dat”) that can be directly inputted into rebuilding analysis.

## **Status of the stock**

The percentage ratio of spawning output in 2002 to  $B_0$  is the population status. The point estimate, from the base model run, for the population status in 2002 is 24.65% (spawning output in 2002 = 9,755). The median estimate, from the MCMC runs, for the population status in 2002 is 24.82%, with a 95% confidence interval of 15.68% and 35.55%, respectively (Figures 32 and 33). These results indicate great uncertainty in estimating the population status, and there is large variability in recruitment (Figures 22 and 34). Given that the population status ranged from the overfishing state (<25%) to the precautionary zone (>25% and <40%), rebuilding analysis is needed to determine harvest projections and target fishing mortalities.

## **Management Recommendations**

The stock has declined since fishing began in the later 1970's. This assessment shows that the spawning output in 2002 was just below 25% of unfished spawning output. A rebuilding analysis using the SSC Default Rebuilding Analysis and the base model outputs was conducted to determine harvest levels and related risks of each harvest levels (He et al. 2003). The rebuilding analysis used twelve simulation scenarios constructed from three factors: (1) whether the recruitments (age 3) for 2003-05 were pre-specified from the 2000-02 midwater survey indices; (2) whether a stock-recruitment relationship or recruit-per-spawner ratios were used to generate future recruitment; and (3) a range for the power coefficient for the midwater juvenile survey index. The analysis indicates a wide range of the Optimum Yield (OY) for 2004 (0-582mt), depending on which simulation scenario is used. If the base model outputs of this assessment (power coefficient = 3) is used, the recruitments for 2003-05 are pre-specified, and recruits-per-spawner ratios are used to generate future recruitments, the estimated OY for 2004 is 284mt with a probability of 60% that the stock will be rebuilt by 2037 (Model 8 in He et al. 2003). Details of each simulation model and its associated harvest levels are presented in He et al. (2003).

## **Research Needs**

1. There is no reliable abundance index for widow rockfish. Recent management measures have been such that catches in both the Oregon bottom trawl fishery and Pacific whiting fishery have been insufficient to derive CPUE estimates for 2000-2002, and will most likely not be suitable to derive CPUE estimates in the future. This means that there will be no abundance index available for future assessments on widow rockfish. The triennial bottom trawl survey can be analyzed and be considered for inclusion in the assessment, although the index has showed no significant trends of widow rockfish probably due to small catches of widow rockfish in the survey. Both 2000 STAR Panel and 2002 STAR Panel have recommended that a rockfish survey by hydro-acoustics or other methods be initiated, possibly in cooperation with the fishing industry.
2. Long-term recruitment index is a key datum series in the stock assessment. Continuation of the midwater juvenile trawl survey and possible increases in sampling intensity and coverage will improve estimation confidence and data quality.

3. For the next assessment, new data should be systematically compared with data and results with those of the 2003 assessment. The next assessment should explicitly report progress on the recommendations made in the 2003 Panel report.
4. Preliminary information for 2002 suggest that discards may have decreased substantially compared to the assumed 16% currently used. New discard data should be analysed and, if warranted, past discard estimates should be adjusted.
5. The assessment assumes a unit stock from the USA/Canada border and south, but there is little information to ascertain the stock structure of widow rockfish. This should be studied through genetic studies and other stock identification techniques.
6. Investigate with recent data whether growth and maturity in the northern area and in the southern area are really different.
7. The model included estimation of a stock-recruitment relationship. Such a relationship can stabilize estimation of recruitments from data-poor portions of the time series, and it can provide a basis for calculation of  $B_0$  and future recruitments. However, inclusion of a relationship with a particular parametric form (the Beverton-Holt or the Ricker relationships) has the potential to influence the trend in recruitment if there are not sufficient data to provide solid information about the trend. Since some assessments use the stock-recruitment relationships internally and others do not, it is recommended that an analysis be conducted to fully investigate the pros and cons of this approach.
8. Considerable uncertainties exist in the estimated stock and recruitment relationship, and it is likely that additional factors besides stock size in US waters are contributing to recruitment variability. The 2003 Panel recommends compiling oceanographic time series and investigating whether these data can be used as covariates in estimating the stock-recruitment relationship of widow rockfish. This investigation should take into account stock structure, including consideration of fish in Canadian waters, and should take a multiple species approach because of the possible synchronicity of rockfish recruitment.
9. Filtering of whiting by-catch data should not exclude tows with widow catches greater than 5 tons nor those outside 2 standard deviations of the standardised values.
10. The current CPUE standardisation treats each 64 Oregon bottom trawlers and 61 geographical units as individual categories. The 2003 Panel recommends that the usefulness of regrouping the vessels and geographical units be investigated. In all standardizations, the straight average index should be compared with the standardized estimates to appraise the magnitude of the effect of the standardization.
11. The Oregon bottom trawl CPUE is an important index in the assessment, yet it is may not be a consistent index of stock size over the period of the assessment because of changes in fishery management and of changes in fishing efficiency of individual fishing units. The data should be analyzed to evaluate the desirability of breaking the series in two or more time periods.
12. The base case model estimates a single selectivity for each of the four fisheries. The 2003 Panel considers that the topic of time-varying selectivity requires further research.
13. Similarly, the weighting of the various indices, including iterative re-weighting of the series and the weights of individual points within each series, should be investigated further.

## **Acknowledgements**

We would like to acknowledge the members of the stock assessment review (STAR) panel, Richard Methot (Chair), Ray Conser, Jean-Jacques Maquire, Rod Moore, Mark Saelens, and Paul Spencer for their constructive reviews and making the review meeting an effective process. We would also like to acknowledge the Groundfish Management Team and Groundfish Advisory Panel representatives for their insightful comments.

## Literature Cited

- Adams, P.B. 1987. The diet of widow rockfish *Sebastodes entomelas* in northern California, pp. 37-41. In: W.H. Lenarz and D.R. Gunderson (eds.), Widow rockfish, proceedings of a workshop, Tiburon, California, December 11-12, 1980. NOAA Tech. Rep. NMFS 48.
- Adams, P.B., editor. 1995. Progress in rockfish recruitment studies. Southwest Fisheries Science Center Administrative Report, Tiburon Laboratory, T-95-01.
- Barss, W.H. and T.W. Echeverria. 1987. Maturity of widow rockfish *Sebastodes entomelas* from the northeastern Pacific, 1977-82, pp. 13-18. In: W.H. Lenarz and D.R. Gunderson (eds.), Widow rockfish, proceedings of a workshop, Tiburon, California, December 11-12, 1980. NOAA Tech. Rep. NMFS 48.
- Boehlert, G.W., W.H. Barss, and P.B. Lamberson. 1982. Fecundity of widow rockfish, *Sebastodes entomelas*, off the coast of Oregon. Fish. Bull. 80:881-884.
- Burnham, K.P. and D.R. Anderson. 1998. Model selection and inference a practical information-theoretic approach. Springer-Verlag New York Inc., NY.
- Chong, E.K.P. and S.H. Zak. 1996. An introduction to optimization. John Wiley & Sons, Inc., New York.
- Dorn, M.W., M.W. Saunders, C.D. Wilson, M.A. Guttormsen, K. Cooke, R. Kieser, and M.E. Wilkins. 1999. Status of the coastal Pacific hake/whiting stock in U.S. and Canada in 1998. In: Appendix to the status of the Pacific coast groundfish fishery through 1999 and recommended acceptable biological catches for 2000, stock assessment and fishery evaluation. Pacific Fishery Management Council, Portland, OR.
- Eschmeyer, W.N., E.S. Herald, and H. Hammann. 1983. A field guide to Pacific coast fishes of North America. Houghton Mifflin Company, Boston, 336p.
- Fournier, D. 1996. An introduction to AD Model Builder for use in nonlinear modeling and statistics. Otter Research Ltd., Sidney, British Columbia, Canada.
- Greiwank, A. and G.F. Corliss, editors. 1991. Automatic differentiation of algorithms: theory, implementation and application. Proceedings of the SIAM Workshop on the Automatic Differentiation of Algorithms, Soc. Indust. And Applied Mathematics, Philadelphia.
- Gunderson, D.R. 1984. The great widow rockfish hunt of 1980-82. N. Am. J. Fish. Man. 4:465-468.
- He, X., A. Punt, A.D. MacCall, and S.V. Ralston. 2003. Rebuilding analysis for widow rockfish in 2003. Draft submitted to the Pacific Fisheries Management Council, May 2003.

- Hightower, J.E. and W.H. Lenarz. 1990. Status of the widow rockfish stock in 1990. In: Status of the Pacific coast groundfish fishery through 1990 and recommended biological catches for 1991 (Appendix F, Volume 2). Pacific Fishery Management Council, Portland, OR.
- Lenarz, W.H. 1987. Ageing and growth of widow rockfish, pp. 31-35. In: W.H. Lenarz and D.R. Gunderson (eds.), Widow rockfish, proceedings of a workshop, Tiburon, California, December 11-12, 1980. NOAA Tech. Rep. NMFS 48.
- MacCall, A.D., S. Ralston, D. Pearson, and E.H. Williams. 1999. Status of bocaccio off California in 1999 and outlook for the next millennium. In: Appendix to the status of the Pacific coast groundfish fishery through 1999 and recommended acceptable biological catches for 2000, stock assessment and fishery evaluation. Pacific Fishery Management Council, Portland, OR.
- Methot, R.D. 1998. Technical description of the stock synthesis assessment program. Unpublished manuscript. NOAA, NMFS, Northwest Fisheries Science Center, Seattle, Washington. 48 p.
- Pearson, D.E. 1996. Timing of hyaline-zone formation as related to sex, location, and year of capture in otoliths of the widow rockfish, *Sebastodes entomelas*. Fish. Bull. 94:190-197.
- Pearson, D.E. and J.E. Hightower. 1991. Spatial and temporal variability in growth of widow rockfish (*Sebastodes entomelas*). NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFSC-167, 43 p.
- Pearson, D.E. and B. Erwin. 1997. Documentation of California's commercial market sampling data entry and expansion programs. NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFSC-240, 62 p.
- Pennington, M. 1986. Some statistical techniques for estimating abundance indices from trawl surveys. Fishery Bulletin, 84:519-525.
- Pennington, M. 1996. Estimating the mean and variance from highly skewed marine data. Fishery Bulletin, 94:498-505.
- Pikitch, E.K., D.L. Erickson, and J.R. Wallace. 1988. An evaluation of the effectiveness of trip limits as a management tool. Northwest and Alaska Fisheries Center, NWFSC Processed Rep. 88-27.
- Otter Research Ltd. 2001. AD Model Builder. Otter Research Ltd, Sydney B.C., Canada.
- Quinn, T.J., II and R.B. Deriso. 1999. Quantitative fish dynamics. Oxford University Press, Inc., New York.
- Quirollo, L.F. 1987. Review of data on historical catches of widow rockfish in northern California, pp. 7-8. In: W.H. Lenarz and D.R. Gunderson (eds.), Widow rockfish,

proceedings of a workshop, Tiburon, California, December 11-12, 1980. NOAA Tech. Rep. NMFS 48.

Ralston, S. 1999. Trends in standardized catch rate of some rockfishes (*Sebastodes* spp.) from the California trawl logbook database. Southwest Fisheries Science Center, Administrative Report SC-99-01.

Ralston, S. and D.F. Howard. 1995. On the development of year-class strength and cohort variability in two northern California rockfishes Fish. Bull. 93:710-720.

Ralston, S., J.N. Ianelli, R.A. Miller, D.E. Pearson, D. Thomas, and M.E. Wilkins. 1996. Status of bocaccio in the Conception/Monterey/Eureka INPFC areas in 1996 and recommendations for management in 1997. In: Status of the Pacific coast groundfish fishery through 1996 and recommended acceptable biological catches for 1997, Pacific Fishery Management Council, Portland, OR.

Ralston, S. and D. Pearson. 1997. Status of the widow rockfish stock in 1997. In: Status of the Pacific coast groundfish fishery through 1997 and recommended acceptable biological catches for 1998. Pacific Fishery Management Council, Portland, OR.

Ralston, S., D.E. Pearson, and J.A. Reynolds. 1998. Status of the chilipepper rockfish stock in 1998. In: Appendix to the status of the Pacific coast groundfish fishery through 1998 and recommended acceptable biological catches for 1999, stock assessment and fishery evaluation. Pacific Fishery Management Council, Portland, OR.

Rogers, J.B. and W.H. Lenarz. 1993. Status of the widow rockfish stock in 1993. In: Status of the Pacific coast groundfish fishery through 1993 and recommended acceptable biological catches for 1994. Pacific Fishery Management Council, Portland, OR.

Rogers, J.B. 2003. Species allocation of *Sebastodes* and *Sebastolobus* sp. Caught by foreign countries of Washington, Oregon, and California, U.S.A. in 1965-1976. NMFS, Northwest Science Center.

Sampson, D.B. and P.R. Crone, editors. 1997. Commercial fisheries data collection procedures for U.S. Pacific coast groundfish. NOAA Tech. Memo. NMFS-NWFSC-31, 189 p.

Stefansson, G. 1996. Analysis of groundfish survey abundance data: combining the GLM and delta approaches. ICES Journal of Marine Sciences, 53:577-588.

Wilkins, M.E. 1986. Development and evaluation of methodologies for assessing and monitoring the abundance of widow rockfish, *Sebastodes entomelas*. Fish. Bull. 84(2):287-310.

Williams, E.H., S. Ralston, A.D. MacCall, D. Woodbury, and D.E. Pearson. 1999. Stock assessment of the canary rockfish resource in the waters off southern Oregon and California in 1999. In: Appendix to the status of the Pacific coast groundfish fishery

through 1999 and recommended acceptable biological catches for 2000, stock assessment and fishery evaluation. Pacific Fishery Management Council, Portland, OR.

Williams, E.H., A.D. MacCall, S. Ralston, and D.E. Pearson. 2000. Status of the widow rockfish resource in Y2K. *In*: Appendix to the status of the Pacific coast groundfish fishery through 2000 and recommended acceptable biological catches for 2001, stock assessment and fishery evaluation. Pacific Fishery Management Council, Portland, OR.

Table 1. U.S. total landings (mt) of widow rockfish by four fisheries type from 1966 to 2002.

Year	Vancouver, Columbia	Oregon Midwater Trawl	Oregon Bottom Trawl	Eureka, Monterey, and Conception	Total
1966	3671			96	3766
1967	3900			249	4149
1968	1693			336	2029
1969	356			21	377
1970	554			0	554
1971	701			0	701
1972	410			13	423
1973	617			207	824
1974	293			280	573
1975	454			358	812
1976	948			412	1360
1977	1318			883	2201
1978	605			502	1107
1979	966			2326	3292
1980	16190			5666	21856
1981	21779			5169	26938
1982	14794			11239	26003
1983	3213	1452	1488	4168	10321
1984	1450	3568	1334	3464	9846
1985	1534	3185	871	3552	9142
1986	2551	2977	1171	2727	9426
1987	3712	4985	1170	2717	12583
1988	3076	4102	1126	2148	10452
1989	3375	4871	1971	2262	12479
1990	2232	3235	2168	2478	10113
1991	1148	1846	1940	1356	6290
1992	935	1149	2624	1327	6036
1993	1703	1755	3385	1347	8190
1994	1062	1678	2382	1244	6366
1995	1077	1585	2278	2012	6952
1996	957	1851	2114	1556	6478
1997	1004	2032	2286	1671	6989
1998	539	926	1331	1294	4090
1999	515	2237	796	901	4450
2000	386	2285	18	1120	3809
2001	297	958	44	485	1794
2002	61	148	6	48	263

Table 2. Management performance in obtaining the harvest guideline for widow rockfish. Harvest guideline and allowable biological catch (ABC) are taken from Council documents. Landings are summaries from the NORPAC and CALCOM databases, and landings are catches multiplied by (1.0-discard rate).

Year	Harvest Guideline	Allowable Biological Catch	Landings	Catch
1989	12100	12400	12479	14856
1990	12400	8900	10113	12039
1991	7000	7000	6290	7488
1992	7000	7000	6036	7186
1993	7000	7000	8190	9750
1994	6500	6500	6366	7579
1995	6500	7700	6952	8276
1996	6500	7700	6478	7712
1997	6500	7700	6989	8320
1998	5090	5750	4090	4869
1999	5090	5750	4450	5298
2000	5090	5750	3809	4535
2001	2300	3727	1794	2136
2002	856	3727	263	313
2003	832	3871		

Table 3. Chronology of the regulatory history of widow rockfish by the Pacific Fishery Management Council.

Date	Regulation
10/13/82	75,000 lb trip limit
1/30/83	30,000 lb trip limit
9/10/83	1,000 lb trip limit
1/1/84	50,000 lb trip limit once per week
5/6/84	40,000 lb trip limit once per week
8/1/84	closed fishery with 1,000 trip limit for incidental catch
9/9/84	closed fishery
1/10/85	30,000 lb trip limit once a week or 60,000 lb trip limit once per two weeks, unlimited trips of less than 3,000 lbs
4/28/85	dropped 60,000 lb biweekly option
7/21/85	3,000 lb trip limit, unlimited number of trips
1/1/86	30,000 lb trip limit, only one weekly landing greater than 3,000 lbs
9/28/86	3,000 lb trip limit, unlimited number of trips
1/1/87	30,000 lb trip limit, only one weekly landing greater than 3000 lbs
11/25/87	closed fishery
1/1/88	30,000 lb trip limit, only one weekly landing greater than 3000 lbs, unlimited number of trips less than 3,000 lbs
9/21/88	3,000 lb trip limit, unlimited number of trips
1/1/89	30,000 lb trip limit, only one weekly landing greater than 3,000 lbs
4/26/89	10,000 lb trip limit once per week
10/11/89	3,000 lb trip limit with unlimited number of trips
1/1/90	15,000 lb trip limit once per week or 25,000 lb trip limit once per two weeks with only one landing greater than 3,000 lbs each week
12/12/90	closed fishery
1/1/91	10,000 lb trip limit per week or 20,000 lb trip limit every two weeks with only one landing greater than 3,000 lbs per week
9/25/91	3,000 lb trip limit with unlimited number of trips
1/1/92	30,000 lbs cumulative landings every 4 weeks
5/9/92	change from 3" mesh to 4.5" mesh in codend for roller gear north of Point Arena
8/12/92	3,000 lb trip limit with unlimited number of trips
12/2/92	30,000 lb cumulative trip limit per 4 weeks
12/1/93	3,000 lb trip limit with unlimited number of trips
1/1/94	30,000 lb cumulative limit per calender month
12/1/94	3,000 lb trip limit with unlimited number of trips
1/1/95	30,000 lb cumulative limit per calender month
4/14/95	45,000 lb cumulative limit per calender month
9/8/95	4.5" mesh applies to entire net and bottom trawl
1/1/96	70,000 lb cumulative limit per two months
9/1/96	50,000 lb cumulative limit per two months
11/1/96	25,000 lb cumulative limit per two months
1/1/97	70,000 lb cumulative limit per two months
5/1/97	60,000 lb cumulative limit per two months
1/1/98	limited entry: 25,000 lb cumulative per two month period, open access: 12,500 lb cumulative per two month period
5/1/98	limited entry: 30,000 lb cumulative per two month period

Table 3 (continued). Chronology of the regulatory history of widow rockfish by the Pacific Fishery Management Council.

Date	Regulation
7/1/98	open access: 3,000 lb cumulative per month
10/1/98	limited entry: 19,000 cumulative per month
1/1/99	limited entry: cumulative limits: phase 1 - 70,000 lbs per period, phase 2 - 16,000 lbs per period, phase 3 - 30,000 lbs per period. Open access: 2,000 lbs per month
5/1/99	limited entry: decrease phase 2 and phase 3 limits to 11,000 lbs
7/2/99	open access: 8,000 lb cumulative limit per month
10/1/99	limited entry: vessels in Oregon and Washington using 30,000 lb cumulative monthly limit must have midwater trawl gear aboard or a state cumulative limit will be imposed
1/1/00	Widow rockfish classified as a shelf species for regulatory purposes, 30,000 lbs/2 months for limited entry trawl, 3,000 lbs/month for limited entry fixed gear and open access
1/1/01	20,000 lbs/2 months for months of Jan-Apr and Sep-Oct; otherwise 10,000 lbs/2 months for midwater limited entry. 1,000 lbs/months for small footrope limited entry. 3,000 lbs/month for fixed gear limited entry. Open access: north - 3,000 lbs/month, south - 3,000 lbs per month with some monthly closures in some areas.
7/1/01	North - limited entry midwater trawl limits: 1,000 lbs/month
10/1/01	closed fishery for all except midwater, which may land 2,000 lbs/month in north for October, then 25,000 lbs/2 months.
1/1/02	North - limited entry trawl: closed through November to midwater trawl except for small bycatch in whiting fishery, in November 13,000 lbs/2 month with no more than 2 trips, small footrope trawl 1000 lbs/month through September, then closed Sept-Oct, then 500 lbs/month Nov-Dec. South - limited entry trawl: midwater closed year round except for a small bycatch in the whiting fishery, small footrope trawl 1,000 lbs/month through July, then closed
1/1/03	North - limited entry trawl: midwater trawl closed through November except for small amount of bycatch in whiting fishery, 12,000 lbs/2 months for Nov-Dec. small footrope trawl - 300 lbs/month Jan-Apr and Nov-Dec, 1000 lbs/month May-Oct. North - limited entry fixed gear: 200 lbs/month. North - open access gear: 200 lbs/month. South - limited entry trawl: same as north for midwater and small footrope trawl. South - limited entry fixed gear: closed Mar-Apr, then variable 100 lbs/2 months to 250 lbs/2 months. South - open access gear: same as limited entry fixed gear.

Table 4a. Propotional age composition of males for the Vancouver-Columbia fishery with the sum across sexes equal to 1. Data are from 1980 to 2002.

Year	Age																		
	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+	
1980	0.000	0.000	0.009	0.022	0.020	0.056	0.096	0.111	0.046	0.029	0.012	0.013	0.006	0.004	0.002	0.002	0.001	0.003	
1981	0.000	0.007	0.024	0.064	0.046	0.024	0.048	0.088	0.068	0.047	0.026	0.017	0.012	0.005	0.004	0.003	0.003	0.009	
1982	0.000	0.008	0.030	0.084	0.031	0.045	0.021	0.021	0.033	0.072	0.045	0.034	0.035	0.021	0.014	0.009	0.005	0.017	
1983	0.000	0.008	0.154	0.113	0.028	0.017	0.014	0.013	0.014	0.018	0.020	0.015	0.015	0.009	0.006	0.007	0.006	0.020	
1984	0.000	0.003	0.054	0.161	0.083	0.033	0.014	0.004	0.006	0.007	0.008	0.013	0.013	0.011	0.007	0.008	0.008	0.029	
1985	0.000	0.008	0.075	0.080	0.125	0.066	0.022	0.009	0.004	0.006	0.005	0.006	0.005	0.003	0.006	0.005	0.003	0.028	
1986	0.000	0.007	0.060	0.174	0.075	0.049	0.014	0.006	0.005	0.005	0.003	0.003	0.005	0.006	0.003	0.002	0.002	0.029	
1987	0.000	0.006	0.024	0.120	0.194	0.046	0.013	0.009	0.003	0.004	0.006	0.004	0.003	0.004	0.004	0.002	0.002	0.011	
1988	0.000	0.000	0.015	0.060	0.137	0.199	0.035	0.013	0.005	0.002	0.001	0.003	0.003	0.001	0.000	0.001	0.001	0.014	
1989	0.000	0.003	0.018	0.093	0.095	0.157	0.087	0.009	0.004	0.001	0.000	0.001	0.000	0.001	0.000	0.000	0.002	0.008	
1990	0.000	0.000	0.025	0.077	0.153	0.068	0.097	0.030	0.011	0.005	0.001	0.000	0.000	0.000	0.001	0.001	0.001	0.007	
1991	0.000	0.001	0.010	0.062	0.114	0.107	0.074	0.044	0.050	0.010	0.004	0.003	0.002	0.001	0.004	0.001	0.001	0.018	
1992	0.000	0.003	0.020	0.031	0.072	0.077	0.082	0.049	0.052	0.029	0.020	0.008	0.005	0.003	0.002	0.000	0.001	0.012	
1993	0.000	0.000	0.017	0.058	0.051	0.063	0.057	0.036	0.029	0.030	0.023	0.020	0.012	0.006	0.005	0.004	0.002	0.014	
1994	0.000	0.001	0.011	0.041	0.087	0.057	0.045	0.037	0.028	0.023	0.026	0.016	0.013	0.011	0.005	0.004	0.003	0.017	
1995	0.001	0.010	0.031	0.056	0.096	0.100	0.064	0.029	0.031	0.019	0.015	0.024	0.010	0.007	0.006	0.007	0.002	0.012	
1996	0.001	0.011	0.054	0.107	0.101	0.061	0.034	0.021	0.015	0.012	0.008	0.007	0.009	0.003	0.004	0.004	0.002	0.008	
1997	0.000	0.003	0.037	0.149	0.129	0.050	0.015	0.010	0.006	0.007	0.007	0.008	0.001	0.003	0.003	0.001	0.001	0.004	
1998	0.000	0.001	0.014	0.043	0.146	0.110	0.040	0.015	0.007	0.009	0.008	0.003	0.002	0.002	0.007	0.001	0.000	0.006	
1999	0.000	0.002	0.011	0.041	0.081	0.107	0.082	0.041	0.023	0.010	0.010	0.009	0.005	0.005	0.004	0.005	0.002	0.005	
2000	0.000	0.000	0.005	0.058	0.113	0.071	0.074	0.073	0.038	0.013	0.012	0.005	0.002	0.009	0.006	0.003	0.002	0.005	
2001	0.000	0.000	0.004	0.051	0.126	0.084	0.062	0.054	0.037	0.039	0.033	0.008	0.017	0.006	0.006	0.006	0.002	0.006	
2002	0.000	0.002	0.020	0.025	0.056	0.097	0.063	0.052	0.023	0.025	0.011	0.014	0.002	0.002	0.005	0.002	0.002	0.003	

Table 4b. Proportional age composition of females for the Vancouver-Columbia fishery with the sum across sexes equal to 1. Data are from 1980 to 2002.

Year	Age																		
	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+	
1980	0.000	0.000	0.009	0.018	0.014	0.026	0.088	0.142	0.085	0.063	0.035	0.018	0.021	0.019	0.005	0.007	0.006	0.013	
1981	0.000	0.007	0.017	0.047	0.044	0.020	0.020	0.062	0.078	0.071	0.037	0.028	0.019	0.010	0.005	0.006	0.005	0.027	
1982	0.000	0.008	0.018	0.060	0.029	0.042	0.019	0.015	0.015	0.049	0.040	0.040	0.033	0.032	0.017	0.015	0.006	0.037	
1983	0.000	0.006	0.153	0.114	0.040	0.021	0.009	0.014	0.013	0.016	0.029	0.023	0.022	0.013	0.010	0.007	0.005	0.028	
1984	0.001	0.002	0.044	0.152	0.075	0.026	0.018	0.005	0.006	0.007	0.011	0.017	0.025	0.024	0.020	0.011	0.014	0.081	
1985	0.000	0.008	0.071	0.081	0.117	0.058	0.028	0.009	0.007	0.005	0.008	0.005	0.012	0.010	0.011	0.007	0.008	0.099	
1986	0.000	0.002	0.053	0.178	0.091	0.070	0.020	0.013	0.004	0.007	0.008	0.006	0.009	0.008	0.008	0.009	0.003	0.061	
1987	0.000	0.004	0.014	0.095	0.224	0.057	0.037	0.026	0.009	0.007	0.004	0.002	0.007	0.008	0.005	0.008	0.004	0.035	
1988	0.000	0.002	0.007	0.056	0.151	0.206	0.035	0.017	0.012	0.008	0.003	0.000	0.003	0.001	0.000	0.001	0.000	0.007	
1989	0.000	0.003	0.007	0.076	0.093	0.184	0.104	0.009	0.010	0.006	0.001	0.001	0.001	0.002	0.000	0.001	0.004	0.020	
1990	0.000	0.001	0.028	0.062	0.116	0.078	0.119	0.059	0.012	0.006	0.003	0.003	0.000	0.001	0.002	0.001	0.001	0.029	
1991	0.000	0.000	0.004	0.054	0.084	0.099	0.066	0.057	0.054	0.011	0.009	0.005	0.004	0.002	0.001	0.003	0.002	0.040	
1992	0.000	0.003	0.023	0.025	0.055	0.091	0.082	0.057	0.069	0.046	0.030	0.012	0.008	0.004	0.001	0.004	0.002	0.024	
1993	0.000	0.001	0.008	0.059	0.038	0.068	0.070	0.055	0.050	0.084	0.048	0.029	0.015	0.009	0.003	0.004	0.002	0.029	
1994	0.004	0.003	0.013	0.047	0.074	0.068	0.044	0.054	0.041	0.043	0.052	0.035	0.025	0.016	0.013	0.008	0.004	0.031	
1995	0.001	0.009	0.032	0.050	0.078	0.082	0.055	0.037	0.023	0.027	0.017	0.021	0.010	0.007	0.011	0.005	0.002	0.014	
1996	0.000	0.002	0.067	0.108	0.105	0.063	0.054	0.024	0.016	0.019	0.015	0.013	0.019	0.005	0.004	0.002	0.002	0.020	
1997	0.000	0.001	0.029	0.167	0.142	0.053	0.033	0.024	0.017	0.018	0.017	0.010	0.007	0.011	0.005	0.002	0.003	0.029	
1998	0.000	0.001	0.012	0.048	0.165	0.153	0.047	0.020	0.023	0.023	0.020	0.021	0.014	0.004	0.011	0.005	0.002	0.017	
1999	0.000	0.001	0.012	0.046	0.067	0.127	0.105	0.053	0.033	0.023	0.015	0.013	0.014	0.009	0.006	0.011	0.005	0.018	
2000	0.000	0.000	0.002	0.053	0.088	0.097	0.077	0.069	0.046	0.021	0.010	0.009	0.006	0.006	0.006	0.009	0.002	0.007	
2001	0.000	0.000	0.002	0.025	0.053	0.090	0.058	0.014	0.031	0.025	0.048	0.035	0.017	0.019	0.004	0.006	0.008	0.023	
2002	0.000	0.002	0.023	0.025	0.027	0.102	0.097	0.042	0.044	0.033	0.028	0.025	0.022	0.009	0.002	0.011	0.005	0.020	

Table 5a. Proportional age composition of males for the Oregon midwater trawl fishery with the sum across sexes equal to 1. Data are from 1984 to 2002.

Year	Age																		
	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+	
1984	0.000	0.001	0.017	0.188	0.114	0.008	0.018	0.006	0.008	0.007	0.015	0.021	0.002	0.007	0.003	0.002	0.001	0.011	
1985	0.000	0.002	0.062	0.067	0.225	0.060	0.008	0.006	0.003	0.000	0.002	0.005	0.014	0.003	0.002	0.000	0.000	0.010	
1986	0.000	0.000	0.005	0.104	0.074	0.195	0.060	0.005	0.005	0.004	0.000	0.000	0.001	0.013	0.004	0.003	0.001	0.008	
1987	0.000	0.000	0.017	0.126	0.222	0.071	0.037	0.019	0.002	0.003	0.003	0.000	0.000	0.002	0.003	0.000	0.001	0.003	
1988	0.000	0.001	0.014	0.076	0.239	0.132	0.032	0.021	0.008	0.000	0.000	0.000	0.001	0.000	0.003	0.002	0.000	0.004	
1989	0.000	0.004	0.016	0.047	0.116	0.189	0.071	0.013	0.014	0.002	0.000	0.000	0.000	0.001	0.002	0.002	0.003	0.006	
1990	0.000	0.003	0.028	0.030	0.058	0.100	0.133	0.068	0.033	0.016	0.008	0.004	0.000	0.001	0.000	0.002	0.000	0.004	
1991	0.000	0.000	0.008	0.066	0.100	0.106	0.065	0.088	0.039	0.010	0.011	0.003	0.002	0.002	0.001	0.000	0.001	0.010	
1992	0.000	0.000	0.036	0.040	0.087	0.083	0.080	0.041	0.086	0.030	0.022	0.014	0.002	0.004	0.000	0.000	0.001	0.013	
1993	0.000	0.000	0.016	0.071	0.055	0.081	0.049	0.039	0.034	0.060	0.026	0.018	0.015	0.006	0.000	0.003	0.001	0.010	
1994	0.000	0.002	0.009	0.076	0.156	0.080	0.047	0.041	0.012	0.020	0.031	0.000	0.002	0.005	0.000	0.000	0.000	0.009	
1995	0.000	0.004	0.017	0.025	0.131	0.095	0.048	0.043	0.032	0.023	0.030	0.007	0.001	0.001	0.000	0.005	0.000	0.001	
1996	0.000	0.008	0.073	0.093	0.071	0.065	0.049	0.034	0.014	0.008	0.024	0.009	0.017	0.008	0.003	0.000	0.005	0.005	
1997	0.000	0.002	0.031	0.240	0.116	0.043	0.026	0.027	0.016	0.013	0.009	0.003	0.014	0.013	0.000	0.000	0.001	0.002	
1998	0.000	0.000	0.012	0.081	0.194	0.112	0.054	0.015	0.025	0.015	0.003	0.007	0.001	0.001	0.009	0.002	0.001	0.004	
1999	0.000	0.001	0.026	0.039	0.110	0.180	0.087	0.022	0.005	0.005	0.000	0.001	0.001	0.000	0.001	0.001	0.000	0.002	
2000	0.000	0.000	0.005	0.032	0.072	0.085	0.107	0.083	0.045	0.030	0.004	0.007	0.009	0.003	0.000	0.000	0.000	0.000	
2001	0.000	0.000	0.001	0.018	0.098	0.099	0.120	0.062	0.050	0.042	0.017	0.006	0.002	0.003	0.002	0.002	0.004	0.004	
2002	0.000	0.005	0.010	0.045	0.075	0.187	0.173	0.053	0.006	0.010	0.011	0.006	0.000	0.015	0.003	0.000	0.007	0.003	

Table 5b. Proportional age composition of females for the Oregon midwater trawl fishery with the sum across sexes equal to 1. Data are from 1984 to 2002.

Year	Age																		
	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+	
1984	0.000	0.001	0.019	0.169	0.181	0.014	0.028	0.006	0.006	0.004	0.027	0.058	0.016	0.008	0.006	0.005	0.006	0.017	
1985	0.000	0.000	0.046	0.066	0.254	0.091	0.009	0.013	0.010	0.000	0.001	0.007	0.019	0.003	0.002	0.001	0.002	0.007	
1986	0.000	0.000	0.010	0.137	0.082	0.168	0.067	0.004	0.011	0.004	0.000	0.000	0.004	0.016	0.001	0.002	0.002	0.009	
1987	0.000	0.001	0.015	0.115	0.203	0.080	0.041	0.022	0.001	0.004	0.002	0.000	0.001	0.001	0.002	0.001	0.000	0.002	
1988	0.001	0.005	0.014	0.076	0.192	0.102	0.027	0.018	0.009	0.004	0.005	0.000	0.001	0.000	0.001	0.004	0.003	0.005	
1989	0.000	0.003	0.023	0.034	0.076	0.195	0.087	0.032	0.016	0.015	0.009	0.002	0.000	0.001	0.000	0.002	0.006	0.012	
1990	0.000	0.000	0.018	0.033	0.054	0.077	0.147	0.106	0.038	0.021	0.009	0.002	0.002	0.001	0.001	0.000	0.000	0.004	
1991	0.000	0.000	0.011	0.063	0.096	0.061	0.068	0.098	0.043	0.013	0.010	0.004	0.003	0.001	0.000	0.000	0.002	0.015	
1992	0.000	0.000	0.023	0.030	0.070	0.075	0.042	0.064	0.089	0.031	0.015	0.006	0.001	0.002	0.002	0.002	0.000	0.008	
1993	0.000	0.001	0.010	0.068	0.036	0.080	0.065	0.036	0.046	0.067	0.034	0.024	0.020	0.010	0.004	0.005	0.002	0.007	
1994	0.000	0.000	0.008	0.049	0.158	0.064	0.056	0.041	0.035	0.025	0.029	0.015	0.021	0.005	0.000	0.002	0.003		
1995	0.000	0.005	0.005	0.031	0.059	0.088	0.089	0.057	0.043	0.039	0.032	0.046	0.013	0.007	0.014	0.001	0.000	0.009	
1996	0.000	0.007	0.067	0.059	0.077	0.080	0.049	0.024	0.039	0.016	0.018	0.023	0.018	0.006	0.001	0.001	0.001	0.027	
1997	0.000	0.003	0.012	0.170	0.082	0.038	0.038	0.017	0.014	0.012	0.013	0.013	0.007	0.017	0.001	0.002	0.000	0.005	
1998	0.000	0.000	0.004	0.037	0.158	0.092	0.048	0.031	0.032	0.015	0.015	0.012	0.004	0.002	0.007	0.001	0.003	0.005	
1999	0.000	0.000	0.024	0.038	0.082	0.184	0.092	0.040	0.020	0.008	0.011	0.007	0.001	0.007	0.004	0.001	0.000	0.001	
2000	0.000	0.000	0.009	0.031	0.071	0.098	0.079	0.091	0.060	0.027	0.016	0.007	0.009	0.004	0.003	0.001	0.006	0.005	
2001	0.000	0.000	0.000	0.013	0.067	0.067	0.071	0.069	0.049	0.060	0.016	0.010	0.008	0.008	0.014	0.008	0.006	0.004	
2002	0.000	0.005	0.005	0.015	0.031	0.087	0.093	0.101	0.030	0.004	0.009	0.003	0.000	0.003	0.003	0.000	0.003	0.003	

Table 6a. Proportional age composition of males for the Oregon bottom trawl fishery with the sum across sexes equal to 1. Data are from 1984 to 1999.

Year	Age																		
	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+	
1984	0.000	0.002	0.034	0.158	0.115	0.018	0.017	0.004	0.004	0.002	0.021	0.015	0.011	0.009	0.007	0.003	0.001	0.010	
1985	0.000	0.003	0.049	0.097	0.195	0.049	0.003	0.005	0.002	0.000	0.001	0.004	0.026	0.000	0.007	0.001	0.000	0.007	
1986	0.000	0.002	0.014	0.200	0.081	0.085	0.058	0.003	0.018	0.005	0.002	0.000	0.001	0.018	0.002	0.001	0.003	0.016	
1987	0.000	0.000	0.011	0.111	0.204	0.072	0.040	0.016	0.003	0.002	0.007	0.000	0.000	0.006	0.005	0.002	0.000	0.008	
1988	0.002	0.011	0.017	0.080	0.208	0.102	0.022	0.011	0.007	0.003	0.000	0.000	0.001	0.000	0.002	0.004	0.001	0.006	
1989	0.000	0.009	0.025	0.051	0.094	0.176	0.064	0.027	0.014	0.008	0.000	0.005	0.000	0.000	0.001	0.001	0.006	0.007	
1990	0.000	0.004	0.047	0.045	0.056	0.068	0.116	0.058	0.021	0.020	0.010	0.004	0.001	0.003	0.000	0.000	0.000	0.012	
1991	0.000	0.000	0.004	0.066	0.100	0.072	0.042	0.078	0.037	0.010	0.012	0.003	0.001	0.004	0.000	0.000	0.001	0.011	
1992	0.000	0.000	0.017	0.022	0.084	0.073	0.059	0.034	0.048	0.018	0.029	0.016	0.004	0.004	0.006	0.002	0.003	0.017	
1993	0.000	0.000	0.006	0.035	0.035	0.088	0.091	0.047	0.033	0.054	0.035	0.023	0.014	0.004	0.002	0.004	0.000	0.017	
1994	0.000	0.003	0.014	0.057	0.107	0.069	0.042	0.017	0.021	0.029	0.024	0.008	0.006	0.005	0.009	0.002	0.000	0.011	
1995	0.000	0.003	0.034	0.109	0.074	0.135	0.039	0.044	0.021	0.018	0.007	0.012	0.005	0.005	0.005	0.000	0.000	0.002	
1996	0.000	0.002	0.079	0.082	0.059	0.058	0.022	0.017	0.017	0.020	0.016	0.002	0.017	0.005	0.002	0.011	0.001	0.007	
1997	0.000	0.006	0.044	0.230	0.118	0.047	0.031	0.021	0.009	0.018	0.007	0.006	0.001	0.006	0.002	0.000	0.000	0.004	
1998	0.000	0.000	0.008	0.051	0.183	0.116	0.035	0.022	0.017	0.020	0.006	0.009	0.000	0.002	0.007	0.000	0.003	0.008	
1999	0.000	0.004	0.028	0.066	0.118	0.177	0.072	0.027	0.009	0.000	0.000	0.007	0.001	0.000	0.000	0.007	0.003		

Table 6b. Proportional age composition of females for the Oregon bottom trawl fishery with the sum across sexes equal to 1. Data are from 1984 to 1999.

Year	Age																		
	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+	
1984	0.000	0.000	0.033	0.135	0.188	0.031	0.018	0.013	0.008	0.005	0.014	0.034	0.017	0.009	0.005	0.006	0.003	0.049	
1985	0.001	0.000	0.023	0.062	0.199	0.121	0.016	0.007	0.007	0.000	0.001	0.026	0.038	0.006	0.006	0.004	0.004	0.030	
1986	0.000	0.001	0.025	0.106	0.062	0.096	0.068	0.007	0.018	0.013	0.000	0.000	0.004	0.044	0.010	0.007	0.005	0.025	
1987	0.000	0.002	0.010	0.119	0.167	0.060	0.051	0.030	0.004	0.004	0.002	0.003	0.000	0.005	0.017	0.014	0.003	0.023	
1988	0.010	0.014	0.009	0.077	0.172	0.103	0.041	0.027	0.015	0.010	0.005	0.006	0.001	0.002	0.006	0.010	0.003	0.010	
1989	0.000	0.001	0.027	0.028	0.068	0.146	0.090	0.038	0.041	0.016	0.006	0.004	0.004	0.004	0.006	0.004	0.010	0.018	
1990	0.000	0.000	0.046	0.036	0.037	0.068	0.137	0.107	0.036	0.017	0.009	0.005	0.007	0.002	0.002	0.001	0.001	0.024	
1991	0.000	0.000	0.007	0.055	0.060	0.065	0.074	0.109	0.058	0.034	0.034	0.007	0.005	0.005	0.002	0.001	0.003	0.037	
1992	0.000	0.000	0.010	0.008	0.082	0.089	0.069	0.058	0.090	0.048	0.032	0.020	0.014	0.005	0.006	0.001	0.003	0.031	
1993	0.000	0.000	0.000	0.025	0.025	0.076	0.073	0.044	0.040	0.066	0.043	0.029	0.017	0.021	0.006	0.009	0.006	0.032	
1994	0.000	0.002	0.009	0.043	0.100	0.063	0.057	0.063	0.046	0.026	0.065	0.029	0.020	0.012	0.012	0.007	0.006	0.016	
1995	0.000	0.005	0.013	0.037	0.109	0.084	0.051	0.039	0.045	0.026	0.017	0.025	0.004	0.002	0.013	0.002	0.000	0.015	
1996	0.000	0.007	0.076	0.102	0.082	0.086	0.051	0.028	0.041	0.032	0.008	0.004	0.040	0.000	0.002	0.010	0.003	0.011	
1997	0.000	0.008	0.031	0.104	0.094	0.030	0.047	0.031	0.019	0.015	0.008	0.013	0.010	0.016	0.005	0.001	0.005	0.014	
1998	0.000	0.000	0.012	0.047	0.141	0.110	0.054	0.024	0.030	0.017	0.026	0.013	0.016	0.003	0.008	0.002	0.001	0.009	
1999	0.000	0.000	0.023	0.058	0.068	0.147	0.063	0.042	0.039	0.009	0.012	0.006	0.008	0.002	0.000	0.001	0.001	0.001	

Table 7a. Proportional age composition of males for the Eureka-Conception fishery with the sum across sexes equal to 1. Data are from 1980 to 2002.

Year	Age																		
	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+	
1980	0.000	0.000	0.001	0.020	0.012	0.007	0.056	0.041	0.069	0.040	0.060	0.011	0.037	0.016	0.003	0.003	0.006	0.012	
1981	0.000	0.008	0.003	0.027	0.027	0.023	0.018	0.063	0.086	0.060	0.032	0.012	0.009	0.015	0.002	0.003	0.009	0.001	
1982	0.000	0.000	0.036	0.005	0.035	0.037	0.031	0.015	0.044	0.109	0.034	0.040	0.024	0.010	0.013	0.013	0.006	0.025	
1983	0.000	0.000	0.020	0.134	0.027	0.032	0.014	0.006	0.007	0.007	0.015	0.017	0.011	0.011	0.004	0.025	0.002	0.042	
1984	0.000	0.000	0.022	0.137	0.145	0.028	0.036	0.014	0.014	0.002	0.010	0.030	0.014	0.004	0.005	0.004	0.004	0.030	
1985	0.000	0.000	0.009	0.062	0.163	0.145	0.013	0.025	0.011	0.002	0.003	0.010	0.022	0.002	0.005	0.003	0.003	0.027	
1986	0.000	0.003	0.042	0.046	0.082	0.124	0.129	0.014	0.022	0.017	0.001	0.001	0.008	0.029	0.006	0.009	0.004	0.038	
1987	0.001	0.000	0.055	0.114	0.044	0.060	0.091	0.112	0.020	0.030	0.021	0.003	0.000	0.019	0.015	0.003	0.011	0.026	
1988	0.000	0.035	0.000	0.066	0.061	0.090	0.061	0.051	0.034	0.014	0.009	0.008	0.003	0.004	0.006	0.016	0.002	0.016	
1989	0.000	0.005	0.109	0.073	0.078	0.119	0.046	0.050	0.020	0.012	0.020	0.016	0.008	0.000	0.000	0.007	0.006	0.009	
1990	0.000	0.000	0.045	0.116	0.029	0.047	0.038	0.056	0.030	0.025	0.016	0.023	0.019	0.014	0.004	0.002	0.008	0.006	
1991	0.000	0.002	0.015	0.119	0.120	0.049	0.038	0.065	0.022	0.016	0.020	0.012	0.002	0.004	0.004	0.003	0.003	0.017	
1992	0.000	0.001	0.011	0.019	0.138	0.095	0.038	0.017	0.044	0.028	0.021	0.019	0.011	0.005	0.016	0.001	0.002	0.023	
1993	0.000	0.000	0.085	0.163	0.096	0.078	0.010	0.002	0.009	0.007	0.011	0.001	0.021	0.005	0.002	0.004	0.001	0.033	
1994	0.002	0.004	0.007	0.070	0.148	0.110	0.065	0.021	0.024	0.007	0.008	0.005	0.006	0.009	0.001	0.005	0.000	0.005	
1995	0.000	0.033	0.039	0.034	0.056	0.197	0.045	0.066	0.058	0.003	0.028	0.007	0.021	0.001	0.004	0.008	0.000	0.003	
1996	0.004	0.006	0.046	0.045	0.067	0.114	0.118	0.033	0.027	0.018	0.015	0.003	0.025	0.007	0.002	0.009	0.013		
1997	0.000	0.002	0.008	0.108	0.041	0.051	0.052	0.048	0.050	0.036	0.027	0.023	0.013	0.005	0.004	0.012	0.006	0.012	
1998	0.000	0.008	0.082	0.061	0.093	0.069	0.054	0.021	0.045	0.025	0.018	0.018	0.005	0.007	0.009	0.000	0.000	0.013	
1999	0.001	0.001	0.019	0.072	0.059	0.101	0.069	0.051	0.027	0.022	0.030	0.016	0.006	0.006	0.006	0.012	0.005	0.031	
2000	0.000	0.000	0.004	0.044	0.061	0.116	0.055	0.044	0.027	0.028	0.009	0.000	0.003	0.003	0.008	0.002	0.002	0.002	
2001	0.000	0.000	0.000	0.010	0.073	0.012	0.064	0.092	0.035	0.040	0.032	0.030	0.042	0.021	0.004	0.003	0.000	0.007	
2002	0.000	0.010	0.002	0.001	0.014	0.031	0.042	0.101	0.028	0.020	0.101	0.030	0.059	0.000	0.030	0.000	0.035	0.040	

Table 7b. Proportional age composition of females for the Eureka-Conception fishery with the sum across sexes equal to 1. Data are from 1980 to 2002.

Year	Age																		
	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+	
1980	0.000	0.000	0.002	0.005	0.003	0.002	0.091	0.162	0.075	0.070	0.076	0.044	0.012	0.005	0.023	0.007	0.003	0.026	
1981	0.000	0.006	0.001	0.019	0.027	0.014	0.006	0.049	0.131	0.095	0.045	0.059	0.044	0.042	0.019	0.008	0.011	0.025	
1982	0.000	0.000	0.020	0.011	0.026	0.022	0.026	0.010	0.028	0.093	0.052	0.042	0.037	0.030	0.027	0.036	0.017	0.044	
1983	0.000	0.009	0.067	0.183	0.045	0.047	0.014	0.010	0.003	0.007	0.032	0.022	0.014	0.026	0.018	0.014	0.023	0.092	
1984	0.000	0.000	0.025	0.124	0.113	0.027	0.029	0.012	0.007	0.003	0.020	0.045	0.010	0.011	0.007	0.007	0.010	0.050	
1985	0.000	0.000	0.002	0.039	0.153	0.144	0.020	0.039	0.006	0.002	0.003	0.010	0.023	0.002	0.006	0.007	0.009	0.031	
1986	0.000	0.001	0.032	0.027	0.073	0.082	0.100	0.007	0.021	0.009	0.005	0.002	0.002	0.028	0.003	0.004	0.004	0.026	
1987	0.001	0.000	0.047	0.095	0.021	0.051	0.051	0.055	0.011	0.010	0.004	0.002	0.001	0.004	0.003	0.006	0.001	0.011	
1988	0.000	0.086	0.037	0.076	0.072	0.055	0.033	0.037	0.021	0.004	0.014	0.020	0.004	0.007	0.004	0.006	0.009	0.039	
1989	0.000	0.003	0.082	0.043	0.042	0.081	0.054	0.038	0.021	0.010	0.008	0.004	0.006	0.006	0.000	0.001	0.001	0.022	
1990	0.000	0.003	0.051	0.109	0.056	0.037	0.089	0.071	0.037	0.024	0.010	0.008	0.006	0.001	0.003	0.001	0.002	0.012	
1991	0.000	0.007	0.008	0.113	0.128	0.061	0.030	0.033	0.023	0.017	0.013	0.011	0.008	0.008	0.007	0.001	0.002	0.018	
1992	0.000	0.000	0.015	0.031	0.108	0.086	0.039	0.030	0.037	0.026	0.026	0.044	0.015	0.000	0.001	0.001	0.006	0.042	
1993	0.000	0.004	0.033	0.135	0.124	0.097	0.037	0.004	0.001	0.010	0.008	0.001	0.001	0.001	0.001	0.005	0.005	0.007	
1994	0.002	0.002	0.022	0.067	0.161	0.066	0.051	0.020	0.026	0.017	0.015	0.007	0.009	0.008	0.006	0.000	0.002	0.023	
1995	0.000	0.008	0.009	0.015	0.050	0.137	0.050	0.068	0.023	0.005	0.008	0.002	0.005	0.008	0.000	0.008	0.000	0.001	
1996	0.005	0.007	0.040	0.043	0.042	0.081	0.058	0.050	0.038	0.030	0.011	0.010	0.012	0.003	0.001	0.007	0.005	0.004	
1997	0.000	0.001	0.007	0.083	0.038	0.056	0.053	0.042	0.065	0.048	0.030	0.020	0.005	0.021	0.006	0.007	0.005	0.014	
1998	0.000	0.002	0.054	0.029	0.076	0.030	0.046	0.045	0.053	0.060	0.028	0.008	0.010	0.006	0.007	0.002	0.003	0.013	
1999	0.000	0.002	0.010	0.074	0.046	0.094	0.042	0.047	0.038	0.022	0.021	0.015	0.014	0.014	0.004	0.009	0.002	0.013	
2000	0.000	0.000	0.007	0.033	0.099	0.073	0.075	0.057	0.039	0.027	0.059	0.033	0.033	0.021	0.002	0.001	0.024	0.007	
2001	0.000	0.000	0.000	0.008	0.060	0.099	0.037	0.065	0.064	0.032	0.038	0.023	0.021	0.001	0.013	0.023	0.034	0.018	
2002	0.000	0.010	0.002	0.001	0.030	0.013	0.041	0.112	0.053	0.072	0.001	0.034	0.032	0.035	0.006	0.006	0.000	0.012	

Table 8. Number of fish and samples collected for each year and fishery of age composition data used in the widow rockfish assessment.

Year	Vancouver-Columbia		Oregon midwater trawl		Oregon bottom trawl		Eureka-Conception	
	Fish	Sample	Fish	Sample	Fish	Sample	Fish	Sample
1980	1775	18					644	70
1981	3050	31					1618	100
1982	3944	40					3145	126
1983	2480	25					2584	167
1984	2193	22	990	33	778	26	2873	137
1985	1591	16	1444	51	606	21	2850	118
1986	2592	27	1974	56	828	22	2568	102
1987	1939	36	1836	62	776	26	2642	101
1988	993	20	1089	38	945	32	1771	74
1989	1494	30	1640	61	963	43	2185	72
1990	2047	41	1410	60	1131	49	2411	85
1991	1739	35	1348	60	1600	77	2024	54
1992	1547	31	654	29	1582	82	736	33
1993	1797	36	1169	50	1201	61	491	20
1994	1398	28	576	22	1379	63	558	25
1995	1650	33	232	12	932	43	235	11
1996	1347	27	338	14	681	27	1008	33
1997	1497	30	523	21	966	40	1097	52
1998	1099	22	239	9	686	30	1180	31
1999	1448	29	254	11	668	26	1158	31
2000	1047	21	465	34			540	14
2001	485	10	543	23			211	7
2002	587	12	183	15			201	10

Table 9. Yearly index estimates from the Santa Cruz/Tiburon Laboratory midwater trawl pelagic juvenile survey from 1984 to 2002.

Year	Index Estimate	CV
1984	5.633	0.4346
1985	14.888	0.4897
1986	0.217	0.5020
1987	4.906	0.2485
1988	3.429	0.2869
1989	0.142	0.4164
1990	0.178	0.4297
1991	1.178	0.3197
1992	0.061	2.0000
1993	0.822	0.2849
1994	0.122	0.4880
1995	0.165	0.4941
1996	0.061	2.0000
1997	0.177	0.4214
1998	0.061	2.0000
1999	0.191	0.5001
2000	0.220	0.3657
2001	0.890	0.2721
2002	6.779	0.3156

Table 10. Oregon bottom trawl logbook catch-per-unit-effort index from 1984 to 1999.

Year	CPUE (lbs./hr.)	CV
1984	331.47	0.2121
1985	100.88	0.1875
1986	227.08	0.2928
1987	169.08	0.2730
1988	93.97	0.2897
1989	164.10	0.1749
1990	78.49	0.1348
1991	73.59	0.1275
1992	83.16	0.1179
1993	53.58	0.1314
1994	100.34	0.1128
1995	109.96	0.1387
1996	94.81	0.1357
1997	97.23	0.1502
1998	56.56	0.1718
1999	84.46	0.1684

Table 11. Indices of widow rockfish catches derived from bycatch in three sectors of the Pacific whiting fisheries. Note that index values after 1998 were not used in this assessment.

Year	Index	CV
<b>Foreign (FOR)</b>		
1976	4.2561	0.1889
1977	3.5294	0.0972
1978	3.8534	0.0718
1979	2.8001	0.0785
1980	6.2652	0.0754
1981	3.2341	0.0795
1982	1.1476	0.2310
1984	9.4606	0.0761
1985	1.3972	0.0817
1986	3.8934	0.0752
1987	2.1810	0.0652
1988	2.4261	0.0940
<b>Joint venture (JV)</b>		
1983	10.5908	0.1113
1985	4.7064	0.1401
1986	4.2898	0.0822
1987	1.0555	0.1028
1988	2.0725	0.0868
1989	4.6436	0.0586
1990	3.1349	0.0703
<b>Domestic (DOM)</b>		
1991	0.5121	0.1137
1992	0.2133	0.0985
1993	0.3035	0.0867
1994	0.5860	0.0570
1995	0.1616	0.0872
1996	0.3362	0.0688
1997	0.3099	0.0619
1998	0.4385	0.0653
1999	0.1769	0.0656
2000	0.1450	0.0695
2001	0.1075	0.0757

Table 12. Model runs with various likelihood components de-emphasized (indicated by bold-italic) and corresponding changes of log-likelihood values in each component. De-emphases were done by multiplying weighting factor for each component by 0.1.

Component de-emphasized	Age composition	Landing	Recruitment Residual	Midwater juvenile survy	Oregon bottom trawl Index	Whiting bycatch - foreign	Whiting bycatch – joint venture	Whiting bycatch - domestic
None (base run)	-457.25	341.49	18.32	-9.80	6.20	0.70	-1.97	3.21
Age composition	<b>-477.56</b>	341.51	18.51	-3.96	7.51	0.92	-1.63	2.96
Landing	-456.98	<b>339.68</b>	18.33	-9.78	6.24	0.69	-1.95	3.21
Recruitment residual	-456.10	341.50	<b>8.04</b>	-9.91	6.17	0.69	-1.98	3.22
Midwater juvenile survey	-456.44	341.50	18.29	<b>-13.27</b>	6.08	0.73	-1.98	3.35
Oregon bottom trawl logbook	-457.02	341.50	18.31	-10.05	<b>5.91</b>	0.72	-2.01	3.28
Whiting bycatch – foreign	-457.25	341.49	18.32	-9.75	6.21	<b>0.66</b>	-1.96	3.20
Whiting bycatch – joint venture	-457.20	341.50	18.32	-9.82	6.16	0.70	<b>-1.99</b>	3.22
Whiting bycatch – domestic	-457.38	341.49	18.32	-9.55	6.24	0.69	-1.95	<b>3.15</b>

Table 13. Estimated parameter values and their standard deviation (SD) for the base model.

Parameter description	Parameter	Estimate	SD
Mean recruitment	$R$	10.551000	0.148580
Recruitment steepness	$h$	0.217140	0.058856
Recruitment deviation in 1958	$R_1^d$	0.104720	0.642680
Recruitment deviation in 1959	$R_2^d$	0.114950	0.645180
Recruitment deviation in 1960	$R_3^d$	0.125360	0.647280
Recruitment deviation in 1961	$R_4^d$	0.128560	0.646680
Recruitment deviation in 1962	$R_5^d$	0.129320	0.644140
Recruitment deviation in 1963	$R_6^d$	0.131250	0.640190
Recruitment deviation in 1964	$R_7^d$	0.013240	0.606230
Recruitment deviation in 1965	$R_8^d$	-0.038203	0.562450
Recruitment deviation in 1966	$R_9^d$	-0.070130	0.500510
Recruitment deviation in 1967	$R_{10}^d$	0.069377	0.420870
Recruitment deviation in 1968	$R_{11}^d$	0.365340	0.317400
Recruitment deviation in 1969	$R_{12}^d$	-0.035161	0.346750
Recruitment deviation in 1970	$R_{13}^d$	0.372800	0.261920
Recruitment deviation in 1971	$R_{14}^d$	0.233010	0.262250
Recruitment deviation in 1972	$R_{15}^d$	0.184440	0.263770
Recruitment deviation in 1973	$R_{16}^d$	1.093900	0.166130
Recruitment deviation in 1974	$R_{17}^d$	-0.175890	0.240320
Recruitment deviation in 1975	$R_{18}^d$	-1.327500	0.279930
Recruitment deviation in 1976	$R_{19}^d$	-1.077300	0.255780
Recruitment deviation in 1977	$R_{20}^d$	-0.777960	0.222260
Recruitment deviation in 1978	$R_{21}^d$	-0.395040	0.176160
Recruitment deviation in 1979	$R_{22}^d$	-1.522100	0.232880
Recruitment deviation in 1980	$R_{23}^d$	0.331310	0.133140
Recruitment deviation in 1981	$R_{24}^d$	0.347740	0.130420
Recruitment deviation in 1982	$R_{25}^d$	-0.512030	0.172020
Recruitment deviation in 1983	$R_{26}^d$	0.256680	0.122990
Recruitment deviation in 1984	$R_{27}^d$	0.784080	0.092010
Recruitment deviation in 1985	$R_{28}^d$	0.001073	0.156710
Recruitment deviation in 1986	$R_{29}^d$	0.228740	0.174090

Table 13. (continued) Estimated parameter values and their standard deviation (SD) for the base model.

Parameter description	Parameter	Estimate	SD
Recruitment deviation in 1987	$R_{30}^d$	0.545860	0.163040
Recruitment deviation in 1988	$R_{31}^d$	0.337950	0.170280
Recruitment deviation in 1989	$R_{32}^d$	-0.443770	0.223280
Recruitment deviation in 1990	$R_{33}^d$	0.426010	0.169890
Recruitment deviation in 1991	$R_{34}^d$	0.031233	0.194390
Recruitment deviation in 1992	$R_{35}^d$	-0.108580	0.213980
Recruitment deviation in 1993	$R_{36}^d$	0.345900	0.203060
Recruitment deviation in 1994	$R_{37}^d$	0.915800	0.185160
Recruitment deviation in 1995	$R_{38}^d$	-0.175660	0.262270
Recruitment deviation in 1996	$R_{39}^d$	0.215940	0.238260
Recruitment deviation in 1997	$R_{40}^d$	-0.214240	0.283310
Recruitment deviation in 1998	$R_{41}^d$	-0.477730	0.313300
Recruitment deviation in 1999	$R_{42}^d$	-0.463610	0.343260
Recruitment deviation in 2000	$R_{43}^d$	0.026063	0.378740
Recruitment deviation in 2001	$R_{44}^d$	-0.144860	0.398790
Recruitment deviation in 2002	$R_{45}^d$	0.099135	0.400010
Selectivity parameter 1 for fishery 1	$\mathbf{h}_{1,1}$	2.508400	0.371340
Selectivity parameter 2 for fishery 1	$\mathbf{h}_{2,1}$	5.836200	0.183620
Selectivity parameter 3 for fishery 1	$\mathbf{h}_{3,1}$	0.147270	0.098170
Selectivity parameter 4 for fishery 1	$\mathbf{h}_{4,1}$	9.872600	14.303000
Selectivity parameter 1 for fishery 2	$\mathbf{h}_{1,2}$	2.683900	0.383700
Selectivity parameter 2 for fishery 2	$\mathbf{h}_{2,2}$	6.155100	0.151870
Selectivity parameter 3 for fishery 2	$\mathbf{h}_{3,2}$	0.236040	0.073958
Selectivity parameter 4 for fishery 2	$\mathbf{h}_{4,2}$	8.713800	5.565300
Selectivity parameter 1 for fishery 3	$\mathbf{h}_{1,3}$	2.392700	0.344100
Selectivity parameter 2 for fishery 3	$\mathbf{h}_{2,3}$	5.994300	0.159700
Selectivity parameter 3 for fishery 3	$\mathbf{h}_{3,3}$	0.209330	0.128850
Selectivity parameter 4 for fishery 3	$\mathbf{h}_{4,3}$	15.639000	4.640200

Table 13. (continued) Estimated parameter values and their standard deviation (SD) for the base model.

Parameter description	Parameter	Estimate	SD
Selectivity parameter 1 for fishery 4	$\mathbf{h}_{1,4}$	2.220100	0.226800
Selectivity parameter 2 for fishery 4	$\mathbf{h}_{2,4}$	5.838900	0.105580
Selectivity parameter 3 for fishery 4	$\mathbf{h}_{3,4}$	0.406790	0.140380
Selectivity parameter 4 for fishery 4	$\mathbf{h}_{4,4}$	19.379000	0.908250
Catchability for midwater juvenile survey	$\log(q_1)$	-31.356000	0.611190
Catchability for Oregon bottom trawl logbook	$\log(q_2)$	-6.375600	0.161830
Catchability for whiting bycatch (foreign)	$\log(q_3)$	-10.177000	0.183660
Catchability for whiting bycatch (joint venture)	$\log(q_4)$	-9.777400	0.311620
Catchability for whiting bycatch (domestic)	$\log(q_5)$	-11.790000	0.211780
Average fishing mortality for Fishery 1	$\log(FF_1)$	-4.010600	0.106790
Average fishing mortality for Fishery 2	$\log(FF_2)$	-2.921200	0.144870
Average fishing mortality for Fishery 3	$\log(FF_3)$	-3.958700	0.148400
Average fishing mortality for Fishery 4	$\log(FF_4)$	-4.752700	0.113500
Deviation of fishing mortality for Fishery 1 in 1966	$\log(FF_{1,1966}^d)$	0.503830	0.149280
Deviation of fishing mortality for Fishery 1 in 1967	$\log(FF_{1,1967}^d)$	0.588560	0.142860
Deviation of fishing mortality for Fishery 1 in 1968	$\log(FF_{1,1968}^d)$	-0.220110	0.135430
Deviation of fishing mortality for Fishery 1 in 1969	$\log(FF_{1,1969}^d)$	-1.765900	0.126620
Deviation of fishing mortality for Fishery 1 in 1970	$\log(FF_{1,1970}^d)$	-1.330200	0.116780
Deviation of fishing mortality for Fishery 1 in 1971	$\log(FF_{1,1971}^d)$	-1.126900	0.106260
Deviation of fishing mortality for Fishery 1 in 1972	$\log(FF_{1,1972}^d)$	-1.685900	0.099091
Deviation of fishing mortality for Fishery 1 in 1973	$\log(FF_{1,1973}^d)$	-1.306300	0.093194
Deviation of fishing mortality for Fishery 1 in 1974	$\log(FF_{1,1974}^d)$	-2.081300	0.088991
Deviation of fishing mortality for Fishery 1 in 1975	$\log(FF_{1,1975}^d)$	-1.678100	0.086701
Deviation of fishing mortality for Fishery 1 in 1976	$\log(FF_{1,1976}^d)$	-1.039200	0.084570
Deviation of fishing mortality for Fishery 1 in 1977	$\log(FF_{1,1977}^d)$	-0.734730	0.084946
Deviation of fishing mortality for Fishery 1 in 1978	$\log(FF_{1,1978}^d)$	-1.434400	0.089091

Table 13. (continued) Estimated parameter values and their standard deviation (SD) for the base model.

Parameter description	Parameter	Estimate	SD
Deviation of fishing mortality for Fishery 1 in 1979	$\log(FF_{1,1979}^d)$	-0.852490	0.093661
Deviation of fishing mortality for Fishery 1 in 1980	$\log(FF_{1,1980}^d)$	2.144100	0.095214
Deviation of fishing mortality for Fishery 1 in 1981	$\log(FF_{1,1981}^d)$	2.697600	0.090513
Deviation of fishing mortality for Fishery 1 in 1982	$\log(FF_{1,1982}^d)$	2.616300	0.082482
Deviation of fishing mortality for Fishery 1 in 1983	$\log(FF_{1,1983}^d)$	1.275500	0.078493
Deviation of fishing mortality for Fishery 1 in 1984	$\log(FF_{1,1984}^d)$	0.377370	0.073821
Deviation of fishing mortality for Fishery 1 in 1985	$\log(FF_{1,1985}^d)$	0.420270	0.072976
Deviation of fishing mortality for Fishery 1 in 1986	$\log(FF_{1,1986}^d)$	0.883230	0.070268
Deviation of fishing mortality for Fishery 1 in 1987	$\log(FF_{1,1987}^d)$	1.157400	0.070356
Deviation of fishing mortality for Fishery 1 in 1988	$\log(FF_{1,1988}^d)$	0.982890	0.070775
Deviation of fishing mortality for Fishery 1 in 1989	$\log(FF_{1,1989}^d)$	1.177200	0.067586
Deviation of fishing mortality for Fishery 1 in 1990	$\log(FF_{1,1990}^d)$	0.855390	0.067060
Deviation of fishing mortality for Fishery 1 in 1991	$\log(FF_{1,1991}^d)$	0.249670	0.068806
Deviation of fishing mortality for Fishery 1 in 1992	$\log(FF_{1,1992}^d)$	0.125560	0.070416
Deviation of fishing mortality for Fishery 1 in 1993	$\log(FF_{1,1993}^d)$	0.798190	0.073786
Deviation of fishing mortality for Fishery 1 in 1994	$\log(FF_{1,1994}^d)$	0.399990	0.081713
Deviation of fishing mortality for Fishery 1 in 1995	$\log(FF_{1,1995}^d)$	0.502920	0.092474
Deviation of fishing mortality for Fishery 1 in 1996	$\log(FF_{1,1996}^d)$	0.423150	0.107670
Deviation of fishing mortality for Fishery 1 in 1997	$\log(FF_{1,1997}^d)$	0.426940	0.127720
Deviation of fishing mortality for Fishery 1 in 1998	$\log(FF_{1,1998}^d)$	-0.179580	0.146940
Deviation of fishing mortality for Fishery 1 in 1999	$\log(FF_{1,1999}^d)$	-0.173910	0.163120
Deviation of fishing mortality for Fishery 1 in 2000	$\log(FF_{1,2000}^d)$	-0.379140	0.183640
Deviation of fishing mortality for Fishery 1 in 2001	$\log(FF_{1,2001}^d)$	-0.546310	0.197970
Deviation of fishing mortality for Fishery 1 in 2002	$\log(FF_{1,2002}^d)$	-2.071400	0.199410
Deviation of fishing mortality for Fishery 2 in 1983	$\log(FF_{2,1983}^d)$	-0.233850	0.116520
Deviation of fishing mortality for Fishery 2 in 1984	$\log(FF_{2,1984}^d)$	0.466440	0.107060
Deviation of fishing mortality for Fishery 2 in 1985	$\log(FF_{2,1985}^d)$	0.271110	0.102800
Deviation of fishing mortality for Fishery 2 in 1986	$\log(FF_{2,1986}^d)$	0.173270	0.097853

Table 13. (continued) Estimated parameter values and their standard deviation (SD) for the base model.

Parameter description	Parameter	Estimate	SD
Deviation of fishing mortality for Fishery 2 in 1987	$\log(FF_{2,1987}^d)$	0.561470	0.092900
Deviation of fishing mortality for Fishery 2 in 1988	$\log(FF_{2,1988}^d)$	0.321030	0.088694
Deviation of fishing mortality for Fishery 2 in 1989	$\log(FF_{2,1989}^d)$	0.607250	0.081619
Deviation of fishing mortality for Fishery 2 in 1990	$\log(FF_{2,1990}^d)$	0.312920	0.074025
Deviation of fishing mortality for Fishery 2 in 1991	$\log(FF_{2,1991}^d)$	-0.194320	0.068843
Deviation of fishing mortality for Fishery 2 in 1992	$\log(FF_{2,1992}^d)$	-0.585160	0.065952
Deviation of fishing mortality for Fishery 2 in 1993	$\log(FF_{2,1993}^d)$	-0.055828	0.062398
Deviation of fishing mortality for Fishery 2 in 1994	$\log(FF_{2,1994}^d)$	-0.035984	0.059635
Deviation of fishing mortality for Fishery 2 in 1995	$\log(FF_{2,1995}^d)$	0.002514	0.061534
Deviation of fishing mortality for Fishery 2 in 1996	$\log(FF_{2,1996}^d)$	0.219960	0.068594
Deviation of fishing mortality for Fishery 2 in 1997	$\log(FF_{2,1997}^d)$	0.256190	0.082663
Deviation of fishing mortality for Fishery 2 in 1998	$\log(FF_{2,1998}^d)$	-0.571830	0.100750
Deviation of fishing mortality for Fishery 2 in 1999	$\log(FF_{2,1999}^d)$	0.369820	0.116330
Deviation of fishing mortality for Fishery 2 in 2000	$\log(FF_{2,2000}^d)$	0.474840	0.138120
Deviation of fishing mortality for Fishery 2 in 2001	$\log(FF_{2,2001}^d)$	-0.286130	0.154620
Deviation of fishing mortality for Fishery 2 in 2002	$\log(FF_{2,2002}^d)$	-2.073700	0.158510
Deviation of fishing mortality for Fishery 3 in 1983	$\log(FF_{3,1983}^d)$	0.446210	0.117390
Deviation of fishing mortality for Fishery 3 in 1984	$\log(FF_{3,1984}^d)$	0.255570	0.105650
Deviation of fishing mortality for Fishery 3 in 1985	$\log(FF_{3,1985}^d)$	-0.196430	0.099582
Deviation of fishing mortality for Fishery 3 in 1986	$\log(FF_{3,1986}^d)$	0.070451	0.095572
Deviation of fishing mortality for Fishery 3 in 1987	$\log(FF_{3,1987}^d)$	-0.021600	0.091146
Deviation of fishing mortality for Fishery 3 in 1988	$\log(FF_{3,1988}^d)$	-0.071484	0.086793
Deviation of fishing mortality for Fishery 3 in 1989	$\log(FF_{3,1989}^d)$	0.577380	0.080468
Deviation of fishing mortality for Fishery 3 in 1990	$\log(FF_{3,1990}^d)$	0.764400	0.072530
Deviation of fishing mortality for Fishery 3 in 1991	$\log(FF_{3,1991}^d)$	0.704600	0.067141
Deviation of fishing mortality for Fishery 3 in 1992	$\log(FF_{3,1992}^d)$	1.075200	0.063646
Deviation of fishing mortality for Fishery 3 in 1993	$\log(FF_{3,1993}^d)$	1.410800	0.059516

Table 13. (continued) Estimated parameter values and their standard deviation (SD) for the base model.

Parameter description	Parameter	Estimate	SD
Deviation of fishing mortality for Fishery 3 in 1994	$\log(FF_{3,1994}^d)$	1.131000	0.057035
Deviation of fishing mortality for Fishery 3 in 1995	$\log(FF_{3,1995}^d)$	1.174000	0.058622
Deviation of fishing mortality for Fishery 3 in 1996	$\log(FF_{3,1996}^d)$	1.155300	0.065993
Deviation of fishing mortality for Fishery 3 in 1997	$\log(FF_{3,1997}^d)$	1.205000	0.080426
Deviation of fishing mortality for Fishery 3 in 1998	$\log(FF_{3,1998}^d)$	0.661440	0.097640
Deviation of fishing mortality for Fishery 3 in 1999	$\log(FF_{3,1999}^d)$	0.191660	0.114280
Deviation of fishing mortality for Fishery 3 in 2000	$\log(FF_{3,2000}^d)$	-3.503500	0.135150
Deviation of fishing mortality for Fishery 3 in 2001	$\log(FF_{3,2001}^d)$	-2.537700	0.150670
Deviation of fishing mortality for Fishery 3 in 2002	$\log(FF_{3,2002}^d)$	-4.492300	0.154170
Deviation of fishing mortality for Fishery 4 in 1966	$\log(FF_{4,1966}^d)$	-2.463800	0.141320
Deviation of fishing mortality for Fishery 4 in 1967	$\log(FF_{4,1967}^d)$	-1.490800	0.136330
Deviation of fishing mortality for Fishery 4 in 1968	$\log(FF_{4,1968}^d)$	-1.170000	0.130540
Deviation of fishing mortality for Fishery 4 in 1969	$\log(FF_{4,1969}^d)$	-3.932100	0.123480
Deviation of fishing mortality for Fishery 4 in 1970	$\log(FF_{4,1970}^d)$	-6.980300	0.115400
Deviation of fishing mortality for Fishery 4 in 1971	$\log(FF_{4,1971}^d)$	-7.001400	0.106780
Deviation of fishing mortality for Fishery 4 in 1972	$\log(FF_{4,1972}^d)$	-4.456500	0.100510
Deviation of fishing mortality for Fishery 4 in 1973	$\log(FF_{4,1973}^d)$	-1.712200	0.094788
Deviation of fishing mortality for Fishery 4 in 1974	$\log(FF_{4,1974}^d)$	-1.437000	0.090702
Deviation of fishing mortality for Fishery 4 in 1975	$\log(FF_{4,1975}^d)$	-1.223400	0.087874
Deviation of fishing mortality for Fishery 4 in 1976	$\log(FF_{4,1976}^d)$	-1.155400	0.085021
Deviation of fishing mortality for Fishery 4 in 1977	$\log(FF_{4,1977}^d)$	-0.427510	0.086073
Deviation of fishing mortality for Fishery 4 in 1978	$\log(FF_{4,1978}^d)$	-0.950500	0.088328
Deviation of fishing mortality for Fishery 4 in 1979	$\log(FF_{4,1979}^d)$	0.661010	0.089668
Deviation of fishing mortality for Fishery 4 in 1980	$\log(FF_{4,1980}^d)$	1.703200	0.088566
Deviation of fishing mortality for Fishery 4 in 1981	$\log(FF_{4,1981}^d)$	1.856700	0.084318
Deviation of fishing mortality for Fishery 4 in 1982	$\log(FF_{4,1982}^d)$	2.939500	0.078086

Table 13. (continued) Estimated parameter values and their standard deviation (SD) for the base model.

Parameter description	Parameter	Estimate	SD
Deviation of fishing mortality for Fishery 4 in 1983	$\log(FF_{4,1983}^d)$	2.206200	0.075402
Deviation of fishing mortality for Fishery 4 in 1984	$\log(FF_{4,1984}^d)$	1.990100	0.073149
Deviation of fishing mortality for Fishery 4 in 1985	$\log(FF_{4,1985}^d)$	2.013200	0.070136
Deviation of fishing mortality for Fishery 4 in 1986	$\log(FF_{4,1986}^d)$	1.722400	0.068621
Deviation of fishing mortality for Fishery 4 in 1987	$\log(FF_{4,1987}^d)$	1.646700	0.067129
Deviation of fishing mortality for Fishery 4 in 1988	$\log(FF_{4,1988}^d)$	1.409900	0.065153
Deviation of fishing mortality for Fishery 4 in 1989	$\log(FF_{4,1989}^d)$	1.535800	0.064997
Deviation of fishing mortality for Fishery 4 in 1990	$\log(FF_{4,1990}^d)$	1.708200	0.066883
Deviation of fishing mortality for Fishery 4 in 1991	$\log(FF_{4,1991}^d)$	1.152100	0.068975
Deviation of fishing mortality for Fishery 4 in 1992	$\log(FF_{4,1992}^d)$	1.187100	0.070837
Deviation of fishing mortality for Fishery 4 in 1993	$\log(FF_{4,1993}^d)$	1.272200	0.075741
Deviation of fishing mortality for Fishery 4 in 1994	$\log(FF_{4,1994}^d)$	1.265100	0.083361
Deviation of fishing mortality for Fishery 4 in 1995	$\log(FF_{4,1995}^d)$	1.828600	0.093823
Deviation of fishing mortality for Fishery 4 in 1996	$\log(FF_{4,1996}^d)$	1.627100	0.109190
Deviation of fishing mortality for Fishery 4 in 1997	$\log(FF_{4,1997}^d)$	1.690900	0.127850
Deviation of fishing mortality for Fishery 4 in 1998	$\log(FF_{4,1998}^d)$	1.445300	0.144900
Deviation of fishing mortality for Fishery 4 in 1999	$\log(FF_{4,1999}^d)$	1.118700	0.162560
Deviation of fishing mortality for Fishery 4 in 2000	$\log(FF_{4,2000}^d)$	1.402500	0.183640
Deviation of fishing mortality for Fishery 4 in 2001	$\log(FF_{4,2001}^d)$	0.656630	0.199280
Deviation of fishing mortality for Fishery 4 in 2002	$\log(FF_{4,2002}^d)$	-1.638200	0.202160

Table 14. Estimated age 3 recruits, age 3+ biomass, spawning biomass, spawning outputs, and annual fishing mortality of widow rockfish from 1958 to 2003 from the base model.

Year	Age 3 Recruits (10 <sup>3</sup> )	Age 3+ Biomass (mt)	Spawning Biomass (mt)	Spawning Output (10 <sup>6</sup> eggs)	Fishing Mortality
1958	42425	220466	102199	39568	0.0000
1959	42862	221913	102256	39569	0.0000
1960	43310	223699	102502	39589	0.0000
1961	43450	225686	103008	39675	0.0000
1962	43484	227766	103779	39870	0.0000
1963	43588	229879	104767	40171	0.0000
1964	38812	230739	105804	40532	0.0000
1965	37029	230746	106795	40920	0.0000
1966	36109	230055	107526	41294	0.0007
1967	41850	226533	105758	40763	0.0019
1968	56748	226743	103517	39987	0.0027
1969	38332	225878	102483	39553	0.0002
1970	56976	231209	103219	39558	0.0000
1971	48694	235105	104283	39775	0.0000
1972	45931	238175	105953	40223	0.0001
1973	114065	258422	108494	40903	0.0016
1974	32197	261645	110677	41586	0.0021
1975	10281	257183	115070	42616	0.0025
1976	13405	249546	119094	44140	0.0027
1977	18353	240538	120479	45821	0.0056
1978	27513	231691	118712	46409	0.0033
1979	9198	218269	113852	45497	0.0167
1980	60680	215045	106614	43132	0.0474
1981	62387	196624	88927	36181	0.0552
1982	25945	168282	70995	28394	0.1631
1983	53363	150954	56512	21674	0.2157
1984	77180	157269	53990	19954	0.2001
1985	28235	153457	53514	19304	0.1785
1986	27537	150183	53840	19015	0.1767
1987	34969	147181	54543	19188	0.2156
1988	27526	137756	53297	19056	0.1758
1989	12418	126337	51429	18741	0.2318
1990	29889	116427	46808	17297	0.2049

Table 14 (continued). Estimated age 3 recruits, age 3+ biomass, spawning biomass, spawning outputs, and annual fishing mortality of widow rockfish from 1958 to 2002 from the base model.

Year	Age 3 Recruits (10 <sup>3</sup> )	Age 3+ Biomass (mt)	Spawning Biomass (mt)	Spawning Output (10 <sup>6</sup> eggs)	Fishing Mortality
1991	20008	106788	43036	16076	0.1335
1992	17124	100875	41335	15525	0.1348
1993	24993	97515	39290	14779	0.2002
1994	41204	96923	35993	13536	0.1687
1995	13379	91781	34015	12701	0.1994
1996	18878	87232	32090	11757	0.1993
1997	11283	80813	31178	11258	0.2079
1998	8153	72565	30036	10898	0.1191
1999	7673	67531	29594	10928	0.1427
2000	12005	62878	27999	10558	0.1347
2001	9806	58524	26086	10027	0.0691
2002	12548	57481	25125	9755	0.0109

Table 15. Estimated numbers of fish (thousands) by age and year for widow rockfish aged 3 to 20+ from 1958 to 2002 from the base model.

Year	Age																			
	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+		
1958	42425	32885	28305	24362	20969	18048	15534	13370	11508	9905	8525	7338	6316	5436	4679	4027	3466	21418		
1959	42862	36516	28305	24362	20969	18048	15534	13370	11508	9905	8525	7338	6316	5436	4679	4027	3466	21418		
1960	43310	36892	31429	24362	20969	18048	15534	13370	11508	9905	8525	7338	6316	5436	4679	4027	3466	21418		
1961	43450	37277	31753	27052	20969	18048	15534	13370	11508	9905	8525	7338	6316	5436	4679	4027	3466	21418		
1962	43484	37397	32085	27330	23284	18048	15534	13370	11508	9905	8525	7338	6316	5436	4679	4027	3466	21418		
1963	43588	37427	32188	27616	23523	20040	15534	13370	11508	9905	8525	7338	6316	5436	4679	4027	3466	21418		
1964	38812	37517	32214	27705	23769	20246	17249	13370	11508	9905	8525	7338	6316	5436	4679	4027	3466	21418		
1965	37029	33405	32291	27727	23846	20458	17426	14846	11508	9905	8525	7338	6316	5436	4679	4027	3466	21418		
1966	36109	31871	28752	27793	23865	20524	17609	14999	12778	9905	8525	7338	6316	5436	4679	4027	3466	21418		
1967	41850	31078	27421	24650	23436	19920	17137	14729	12570	10730	8333	7186	6196	5342	4606	3971	3423	21202		
1968	56748	36020	26738	23497	20733	19488	16569	14282	12301	10520	8999	7003	6051	5228	4516	3901	3368	20952		
1969	38332	48842	30996	22962	19996	17544	16490	14032	12107	10438	8935	7650	5959	5154	4457	3854	3332	20808		
1970	56976	32993	42037	26667	19721	17155	15051	14150	12044	10393	8962	7673	6571	5120	4429	3831	3313	20755		
1971	48694	49039	28396	36160	22879	16893	14695	12897	12129	10326	8914	7689	6585	5641	4396	3804	3291	20682		
1972	45931	41911	42206	24422	31000	19576	14455	12580	11044	10390	8849	7642	6594	5649	4841	3774	3266	20594		
1973	114065	39533	36072	36311	20972	26590	16792	12402	10795	9480	8920	7599	6563	5664	4854	4160	3243	20513		
1974	32197	98176	34024	31021	31121	17936	22741	14365	10613	9241	8117	7641	6511	5626	4857	4164	3570	20400		
1975	10281	27712	84496	29268	26627	26675	15372	19492	12315	9100	7925	6963	6555	5587	4829	4170	3576	20596		
1976	13405	8849	23850	72670	25096	22787	22825	13156	16686	10545	7794	6789	5966	5619	4791	4142	3578	20758		
1977	18353	11538	7615	20503	62179	21408	19436	19476	11230	14250	9009	6662	5806	5105	4810	4104	3550	20876		
1978	27513	15797	9929	6542	17486	52775	18166	16501	16545	9546	12121	7668	5674	4949	4355	4107	3507	20910		
1979	9198	23680	13595	8537	5604	14939	45081	15521	14103	14145	8164	10369	6563	4858	4239	3732	3521	20954		
1980	60680	7916	20374	11663	7238	4712	12549	37886	13052	11867	11911	6881	8748	5543	4109	3591	3168	20852		

Table 15 (continued). Estimated numbers of fish (thousand) by age and year for widow rockfish aged 3 to 20+ from 1958 to 2002 from the base model.

Year	Age																		
	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+	
1981	62387	52214	6795	17081	8799	5105	3320	8924	27218	9475	8706	8832	5157	6629	4247	3185	2816	19237	
1982	25945	53677	44753	5608	11880	5495	3188	2107	5763	17892	6341	5931	6125	3641	4765	3108	2372	16956	
1983	53363	22318	45935	36495	3710	6847	3146	1852	1245	3465	10956	3957	3776	3984	2424	3251	2177	14245	
1984	77180	45919	19160	38594	27677	2590	4757	2205	1312	891	2509	8022	2931	2831	3025	1864	2536	13142	
1985	28235	66417	39444	16180	29767	19600	1827	3393	1593	959	660	1880	6083	2249	2199	2378	1483	12744	
1986	27537	24297	57059	33353	12611	21534	14129	1329	2494	1183	720	500	1441	4711	1760	1739	1902	11619	
1987	34969	23697	20875	48250	25980	9132	15553	10303	980	1859	891	548	385	1120	3702	1398	1396	11052	
1988	27526	30092	20355	17603	36812	18091	6347	10956	7367	711	1369	666	415	295	870	2911	1112	10116	
1989	12418	23688	25857	17227	13728	26656	13079	4639	8105	5516	539	1049	516	325	234	696	2349	9220	
1990	29889	10686	20345	21778	13034	9409	18230	9075	3271	5807	4015	398	787	392	251	183	551	9354	
1991	20008	25721	9179	17167	16721	9184	6607	12945	6526	2383	4285	3000	301	603	304	197	145	8041	
1992	17124	17219	22110	7800	13723	12636	6922	5015	9905	5035	1853	3361	2372	240	484	246	161	6780	
1993	24993	14737	14800	18778	6228	10367	9510	5241	3824	7608	3897	1446	2642	1880	192	390	200	5726	
1994	41204	21508	12660	12493	14452	4412	7311	6774	3776	2788	5616	2912	1094	2023	1457	150	310	4803	
1995	13379	35459	18482	10723	9798	10556	3211	5367	5023	2829	2111	4295	2250	854	1595	1161	121	4188	
1996	18878	11513	30456	15594	8258	6951	7450	2287	3863	3656	2082	1571	3235	1715	658	1246	917	3487	
1997	11283	16245	9890	25723	12030	5855	4907	5314	1650	2822	2703	1559	1190	2480	1331	517	990	3571	
1998	8153	9709	13954	8346	19753	8460	4099	3471	3805	1197	2072	2010	1174	908	1915	1040	409	3687	
1999	7673	7016	8346	11867	6722	15151	6467	3149	2683	2960	937	1633	1595	938	730	1553	850	3393	
2000	12005	6604	6032	7097	9469	5030	11318	4877	2400	2066	2303	736	1295	1276	757	594	1273	3525	
2001	9806	10332	5678	5133	5690	7139	3788	8604	3746	1862	1619	1821	587	1042	1035	619	490	4001	
2002	12548	8439	8888	4858	4257	4576	5737	3059	6984	3056	1527	1334	1507	488	870	867	520	3802	

Table 16. Estimated numbers of fish caught (thousand) by age and year for widow rockfish aged 3 to 20+ from 1958 to 2002 from the base model.

Year	Age																	
	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1958	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1959	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1960	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1961	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1962	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1963	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1964	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1965	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1966	1	11	105	525	670	570	461	366	290	207	164	129	101	79	61	47	36	197
1967	1	12	113	521	738	622	505	406	323	255	183	144	113	89	69	53	41	222
1968	1	7	55	246	326	306	247	200	162	129	103	74	58	46	36	27	21	113
1969	0	2	12	46	60	53	47	37	30	24	19	15	10	8	6	5	4	21
1970	0	2	24	80	88	75	62	54	43	34	27	21	16	11	9	7	5	30
1971	0	3	20	132	125	91	74	61	53	41	33	26	20	15	11	8	6	36
1972	0	2	17	52	99	62	43	35	29	25	19	15	12	9	7	5	4	21
1973	1	3	28	142	124	158	95	66	55	45	40	31	25	20	15	12	8	43
1974	0	6	18	79	121	71	87	53	38	31	26	23	18	15	11	9	6	31
1975	0	2	61	102	142	145	81	98	59	42	34	28	25	19	15	12	9	42
1976	0	1	26	398	208	190	183	100	120	72	50	40	33	28	22	17	13	63
1977	0	2	13	174	801	280	245	235	129	156	93	65	52	42	36	27	20	102
1978	0	2	9	30	120	371	123	108	103	57	68	40	28	22	18	15	11	56
1979	0	8	41	119	120	333	988	332	293	284	158	191	114	78	62	48	39	192
1980	14	20	491	1340	1216	795	2030	5829	1902	1631	1535	827	974	566	380	297	231	1321

Table 16 (continued). Estimated numbers of fish caught (thousand) by age and year for widow rockfish aged 3 to 20+ from 1958 to 2002 from the base model.

Year	Age																		
	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+	
1981	22	203	260	3053	2251	1306	813	2077	5991	1963	1690	1597	863	1017	592	399	313	1875	
1982	13	286	2186	1209	3663	1717	967	617	1620	4815	1625	1439	1394	769	920	538	361	2223	
1983	12	53	1018	4036	653	1230	544	305	195	512	1522	513	453	437	239	284	164	908	
1984	14	84	336	3728	4566	435	758	330	184	116	302	887	296	257	244	131	152	658	
1985	5	115	644	1421	4420	2964	263	461	203	114	73	192	567	190	165	156	83	594	
1986	4	41	929	2946	1862	3224	2008	177	311	137	77	49	129	381	127	110	103	529	
1987	6	45	394	5097	4620	1637	2628	1623	143	250	110	61	39	102	297	98	84	561	
1988	4	46	315	1537	5437	2694	891	1433	892	79	140	62	35	22	58	169	55	425	
1989	2	47	515	1938	2604	5100	2360	781	1264	792	71	125	56	31	20	52	151	501	
1990	5	20	372	2187	2201	1613	2970	1389	468	772	493	45	81	36	21	13	34	489	
1991	2	31	108	1136	1897	1062	726	1337	629	213	354	227	21	37	17	9	6	281	
1992	2	22	272	524	1562	1476	775	532	990	471	161	270	174	16	29	13	7	260	
1993	4	27	265	1848	1026	1743	1527	794	544	1008	478	163	272	174	16	28	13	309	
1994	6	32	187	1032	2036	634	1001	873	456	313	582	277	95	157	101	9	16	213	
1995	3	68	338	1049	1603	1768	516	817	721	381	265	499	240	82	138	88	8	232	
1996	3	21	530	1503	1355	1163	1188	344	544	479	253	175	328	157	54	89	56	181	
1997	2	30	180	2579	2049	1018	814	831	242	385	342	181	126	237	113	39	64	194	
1998	1	11	155	498	1999	880	409	329	341	101	163	146	78	55	104	49	17	126	
1999	1	8	93	804	817	1862	745	336	263	265	76	119	104	54	37	68	32	105	
2000	1	7	63	452	1093	585	1228	488	220	172	173	50	78	68	35	24	43	97	
2001	1	6	32	174	348	440	218	455	181	82	64	65	19	30	26	13	9	59	
2002	0	1	8	26	43	46	53	26	53	21	9	7	7	2	3	3	1	8	

Table 17. Sensitivity analysis showing changes in spawning outputs and total log-likelihood values in response to changes in natural mortality ( $M$ ). Spawning outputs are for the first year ( $\text{SO}_{1958} = B_0$ ), the last year ( $\text{SO}_{2002}$ ), and percentage of  $\text{SO}_{2002}/\text{SO}_{1958}$ .

Change in $M$	$\text{SO}_{1968}$	$\text{SO}_{2002}$	% $\text{SO}_{2002}/\text{SO}_{1968}$	Likelihood
$M = 0.09$	45637	10394	22.78	-98.88
$M = 0.11$	43282	10256	23.70	-98.81
$M = 0.13$	41499	9918	23.90	-100.27
Base run ( $M = 0.15$ )	39566	9755	24.65	-103.35
$M = 0.17$	37603	9950	26.46	-108.24
$M = 0.19$	34552	11287	32.67	-115.57
$M = 0.21$	35791	16714	46.70	-125.43

Table 18. Sensitivity analysis showing changes in spawning outputs and total log-likelihood values in response to changes in the power coefficient for the midwater juvenile survey index ( $p$ ). Spawning outputs are for the first year ( $\text{SO}_{1958} = B_0$ ), the last year ( $\text{SO}_{2002}$ ), and percentage of  $\text{SO}_{2002}/\text{SO}_{1958}$ .

Change in $p$	$\text{SO}_{1968}$	$\text{SO}_{2002}$	% $\text{SO}_{2002}/\text{SO}_{1968}$	Likelihood
$p = 1.0$	39591	8876	22.42	-105.80
$p = 2.0$	39730	8895	22.39	-103.49
Base run ( $p = 3.0$ )	39566	9755	24.65	-103.35
$p = 4.0$	39519	10711	27.11	-104.48
$p = 5.0$	39569	11538	29.16	-106.26

Figure 1. U.S. landings (mt) of widow rockfish by four fisheries from 1966 to 2002. Four fisheries are defined by area and gear type.

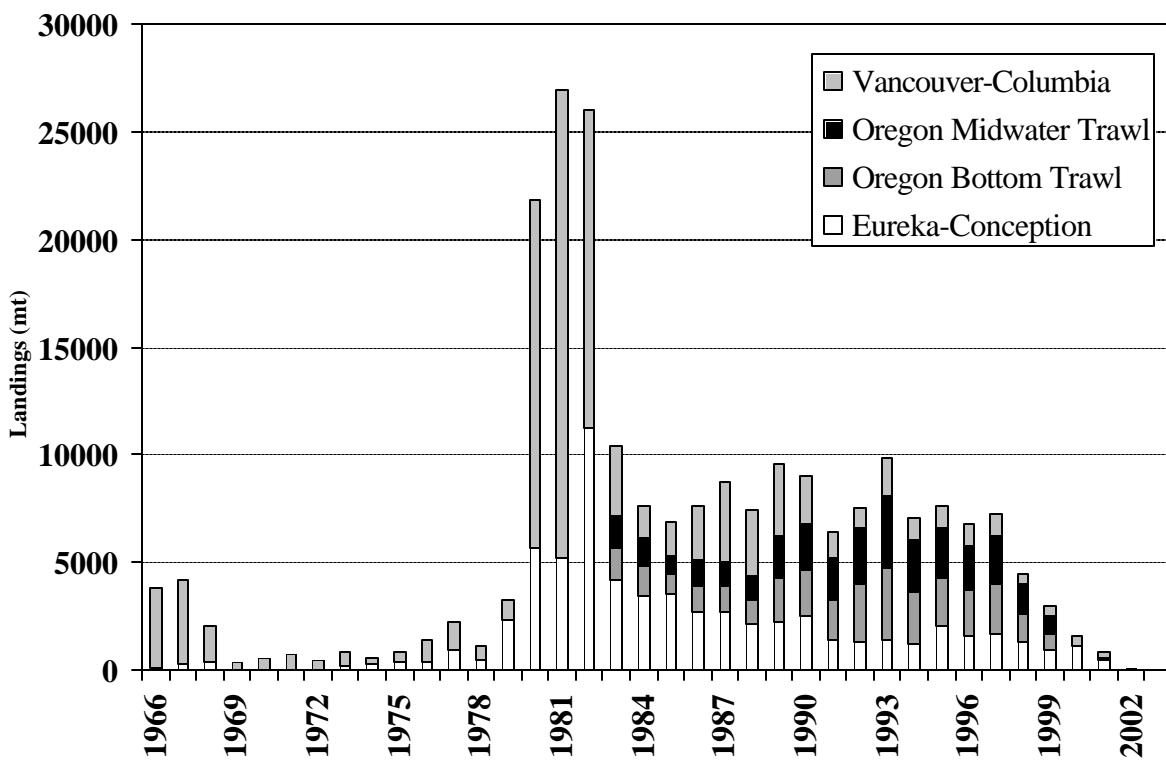


Figure 2. Growth functions for widow rockfish by sex from north and south of  $43^{\circ}$  latitude used in this assessment.

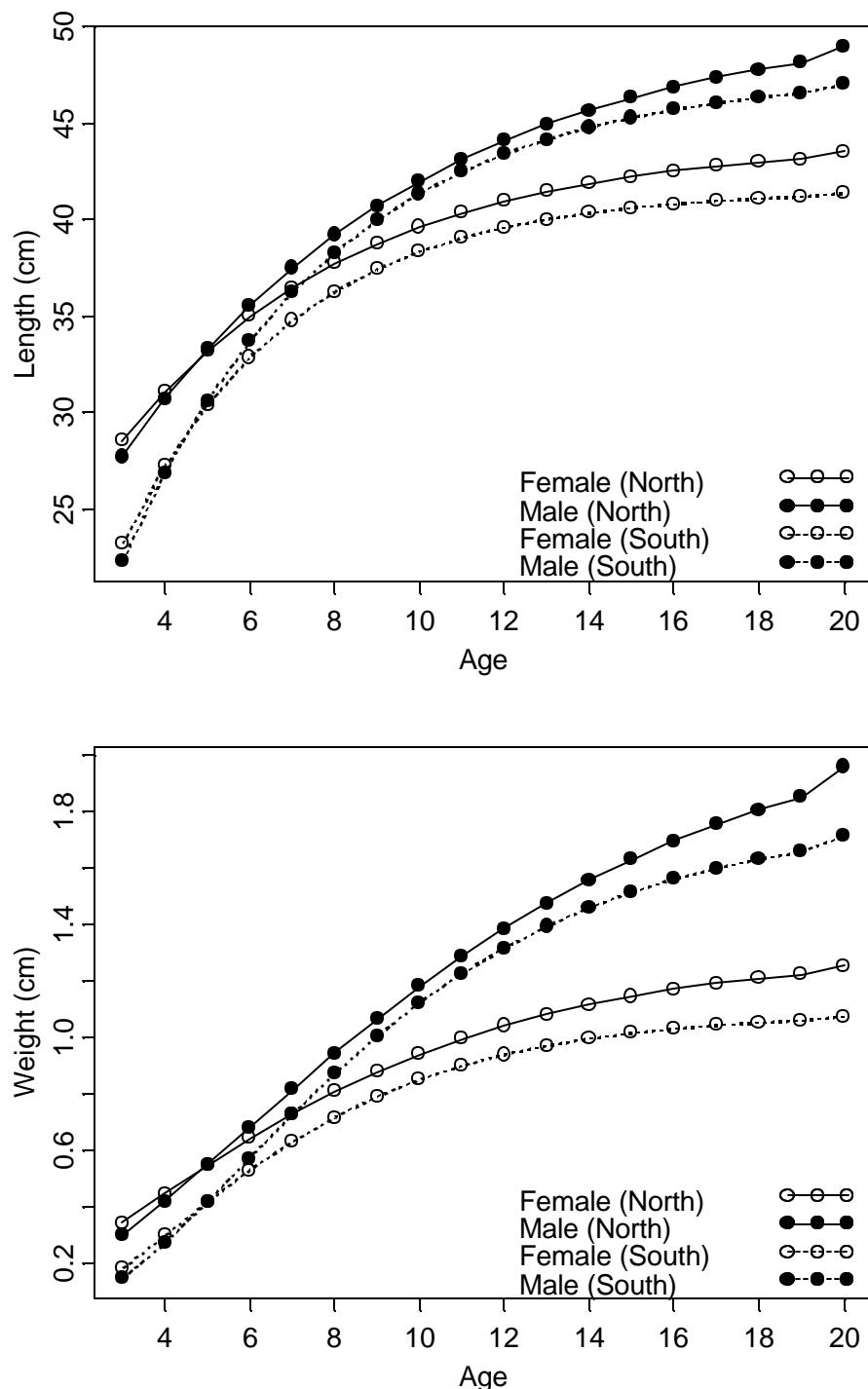


Figure 3. Fecundity and maturity for widow rockfish from north and south of  $43^{\circ}$  latitude used in this assessment.

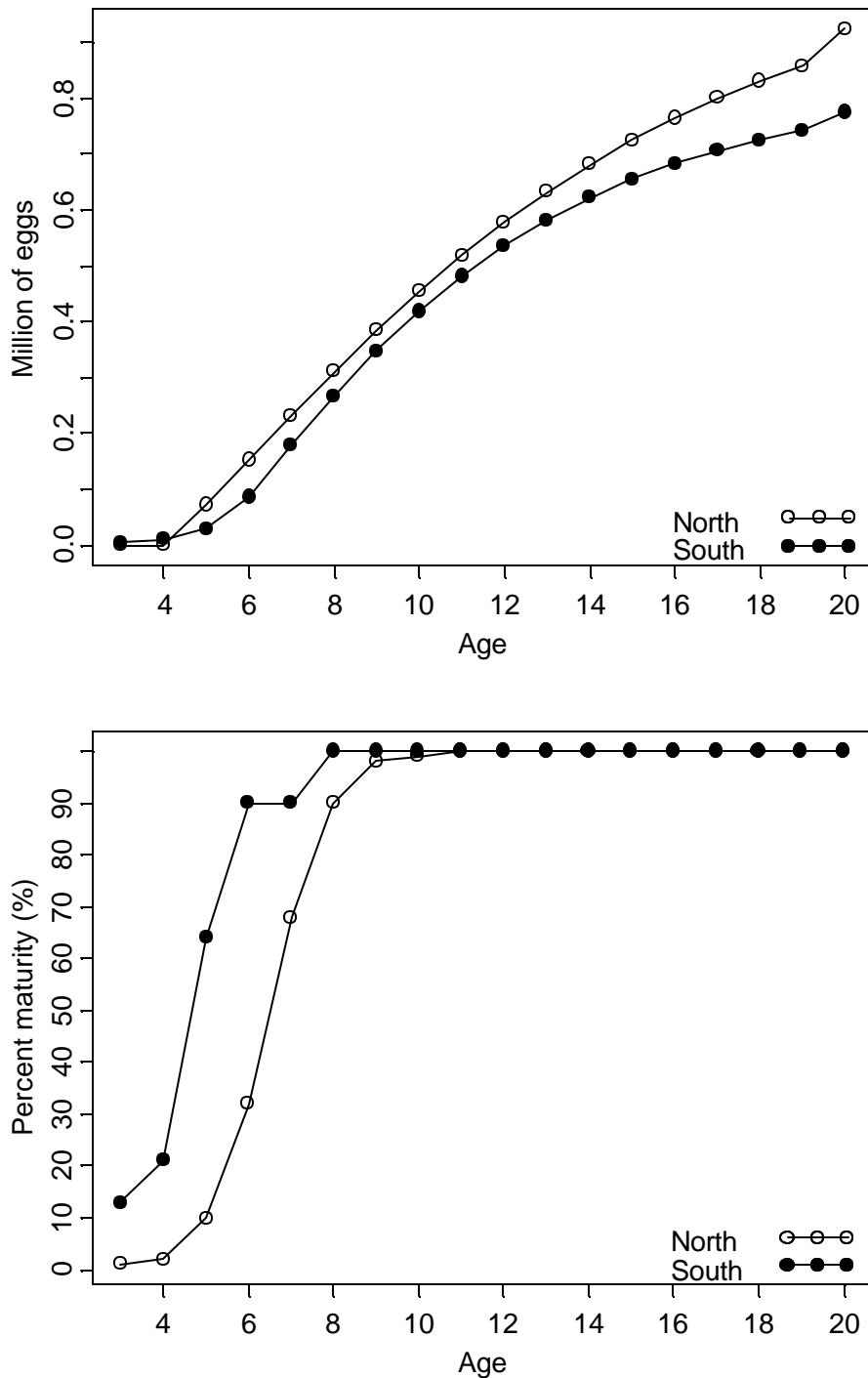


Figure 4. Proportional age composition data for the Vancouver-Columbia combined fishery, by sex and year with the sum across sexes equal to 1.

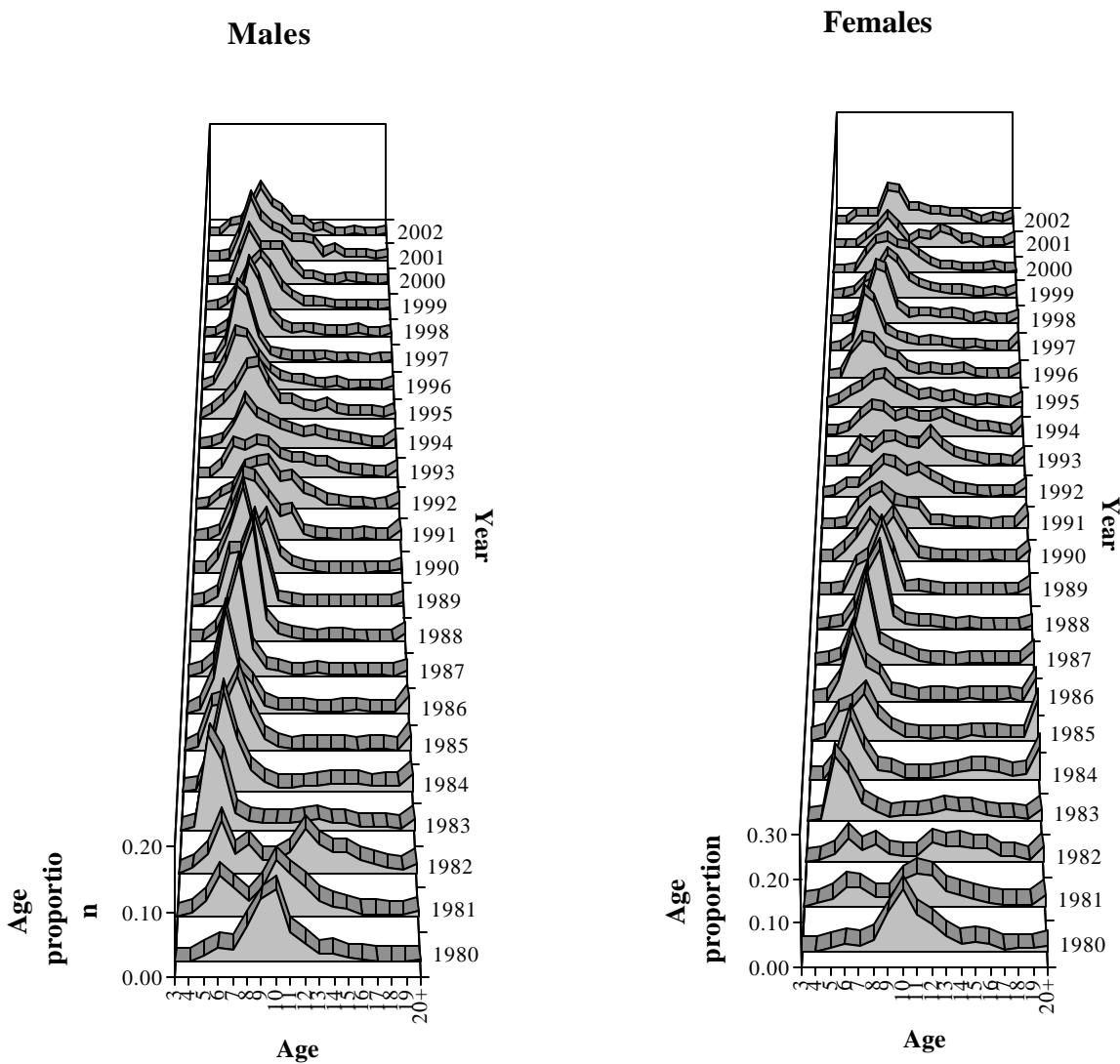


Figure 5. Proportional age composition data for the Oregon midwater trawl fishery, by sex and year with the sum across sexes equal to 1.

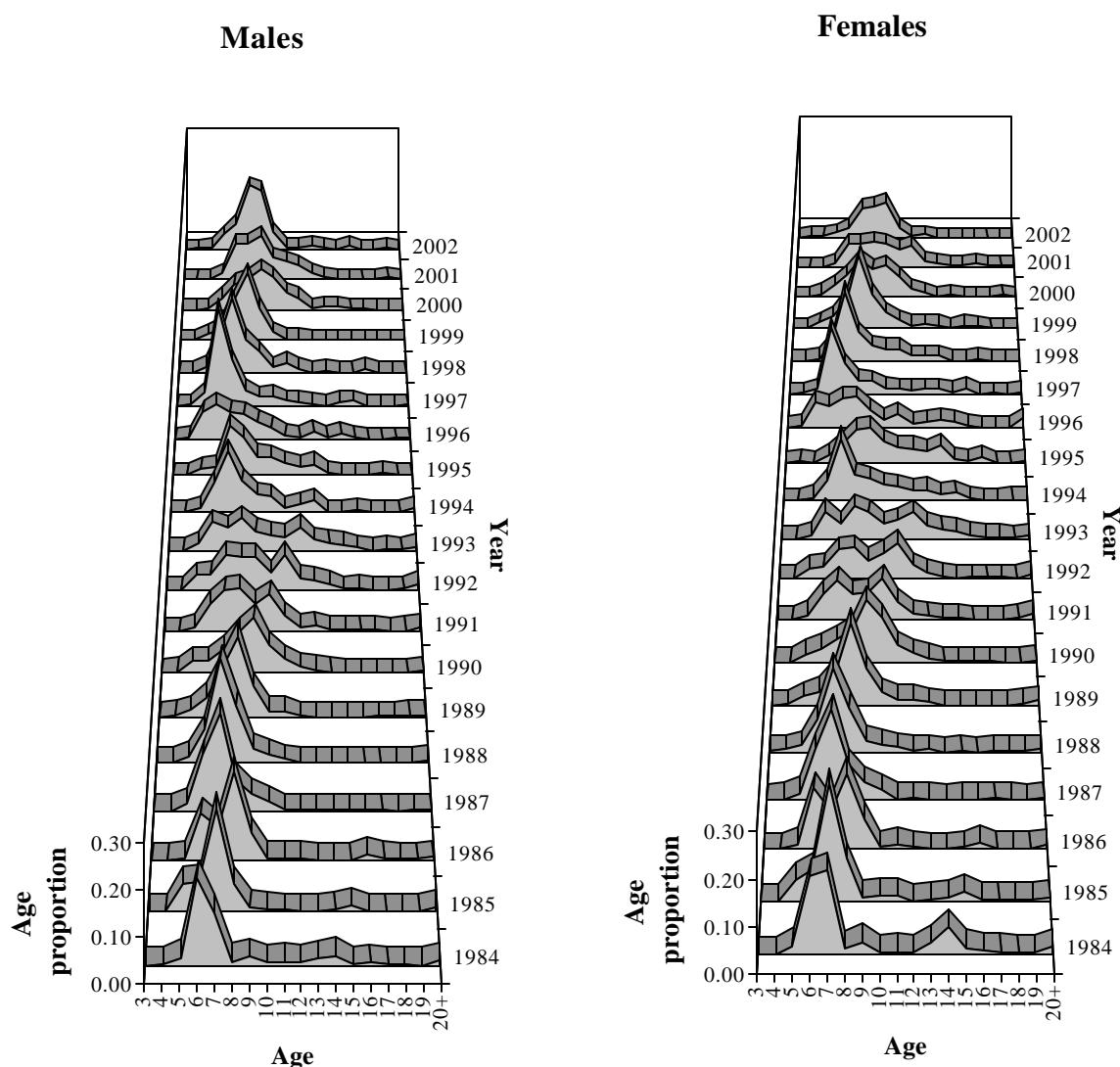


Figure 6. Proportional age composition data for the Oregon bottom trawl fishery, by sex and year with the sum across sexes equal to 1.

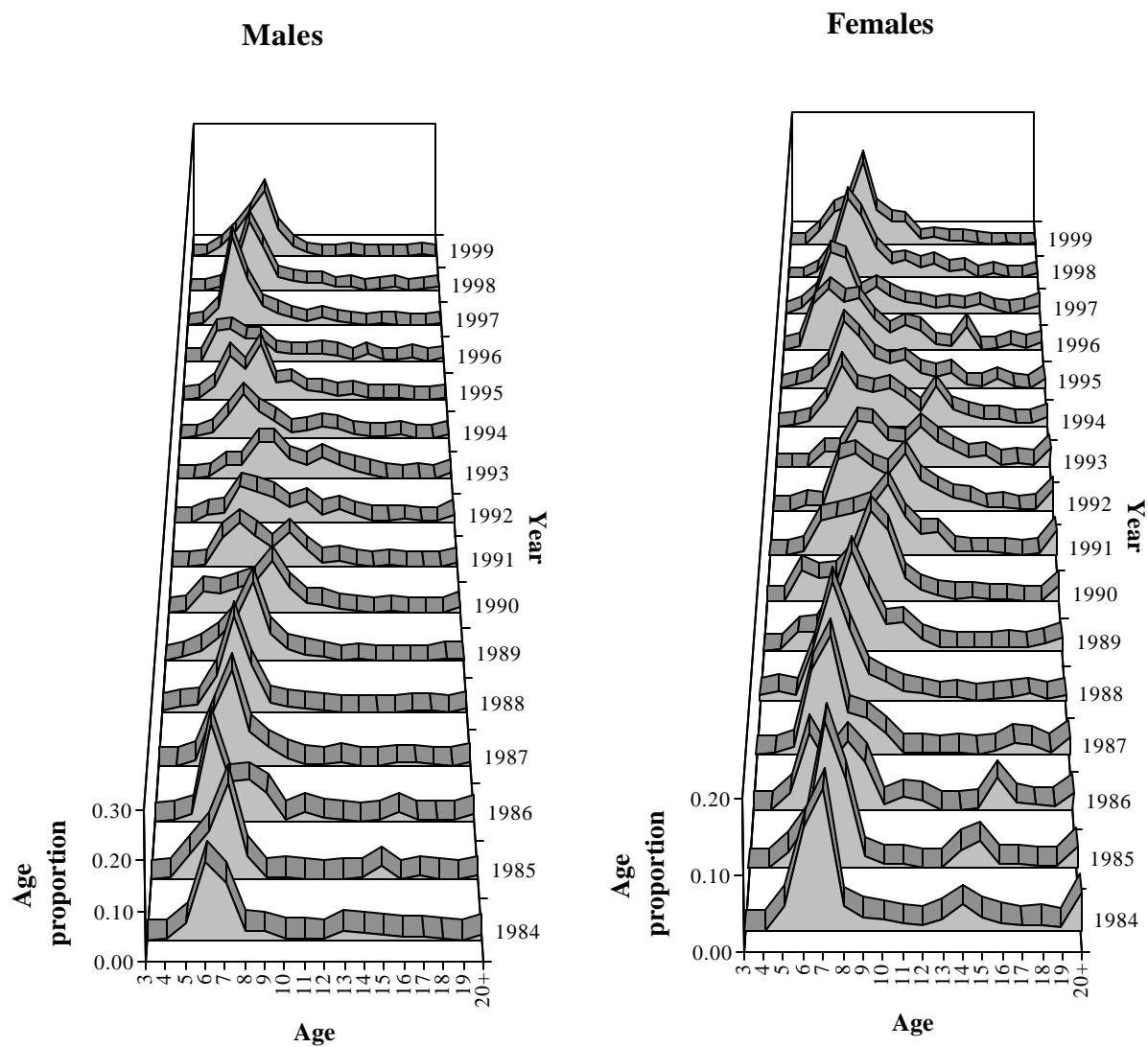


Figure 7. Proportional age composition data for the Eureka-Conception combined fishery, by sex and year with the sum across sexes equal to 1.

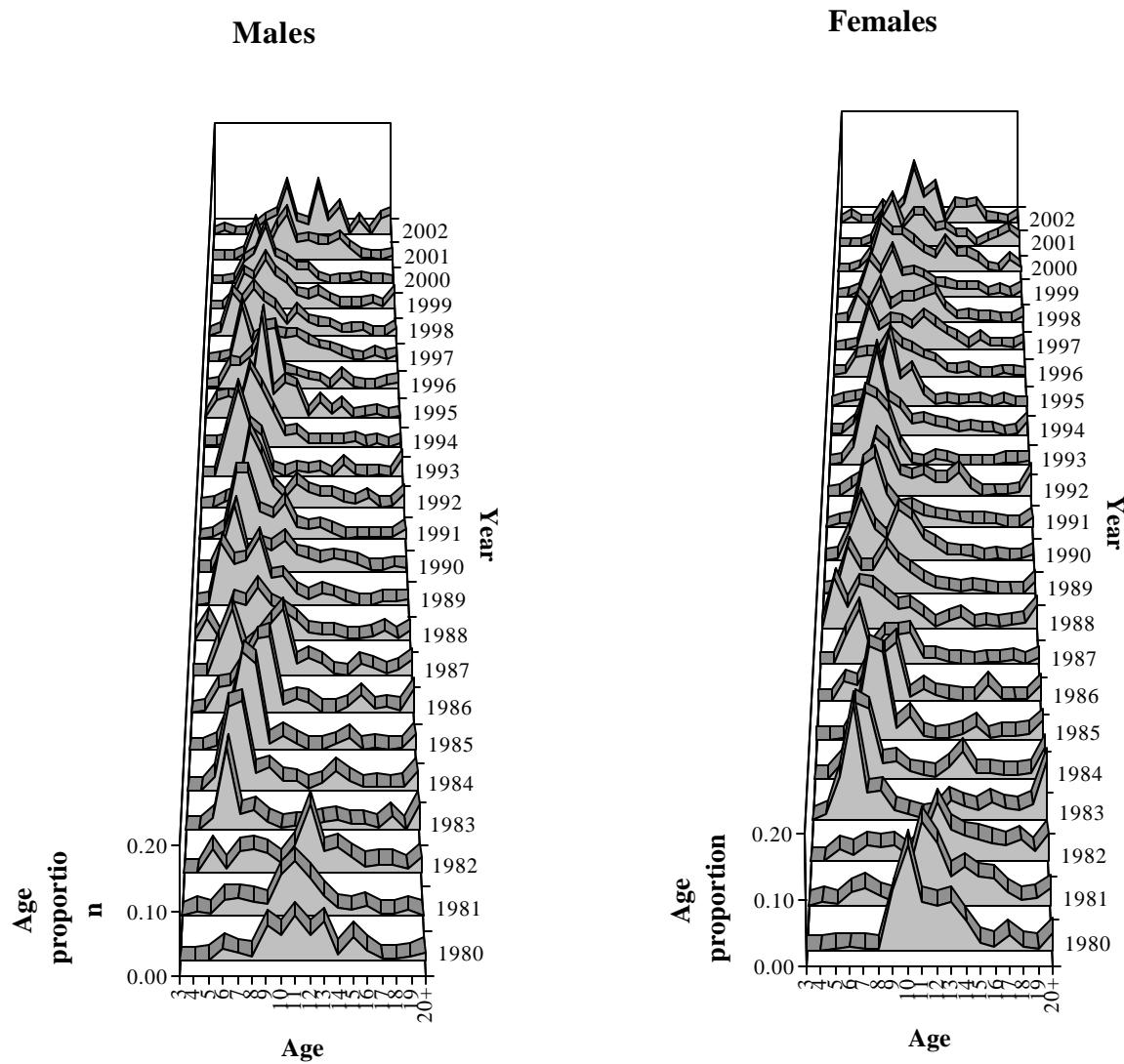


Figure 8. Differences in proportions between age composition data used in 2000 and this assessment (2000 estimate – this estimate) for the Vancouver-Columbia fishery. Dark circles represent positive differences and open circles represent negative differences. The largest circle represents approximately difference of 0.04.

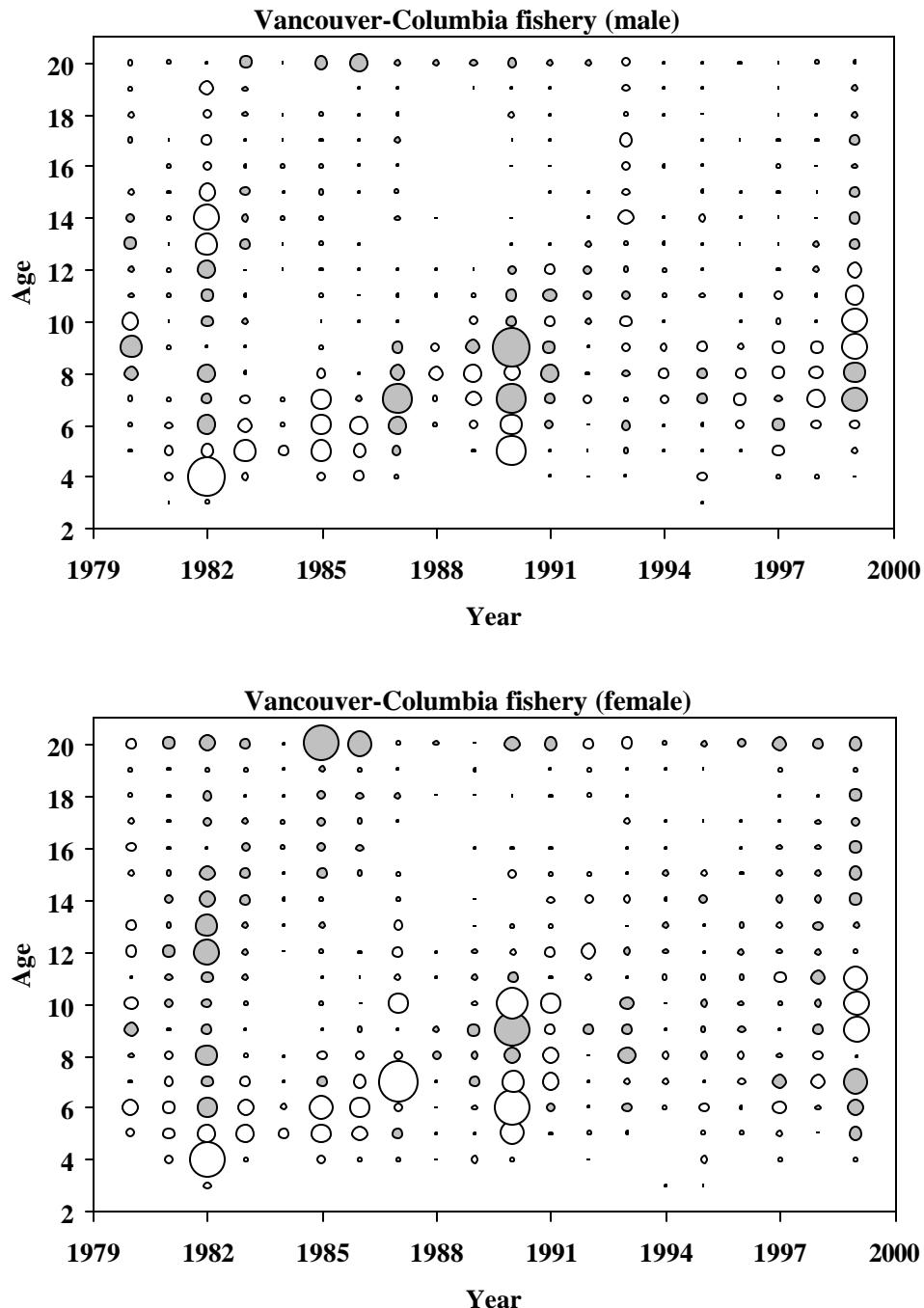


Figure 9. Differences in proportions between age composition data used in 2000 and this assessment (2000 estimate – this estimate) for the Oregon midwater trawl fishery. Dark circles represent positive differences and open circles represent negative differences. The largest circle represents approximately difference of 0.04.

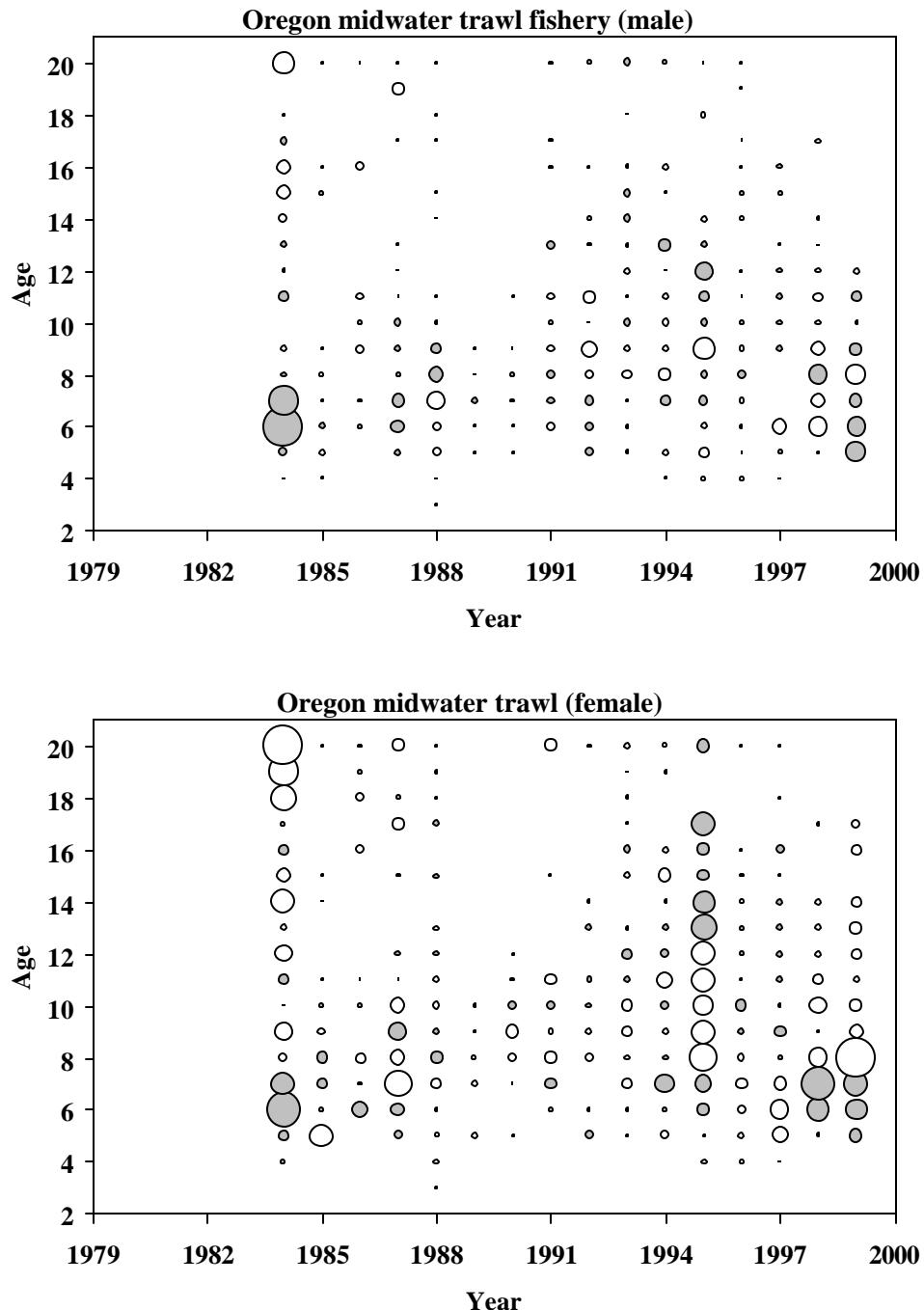


Figure 10. Differences in proportions between age composition data used in 2000 and this assessment (2000 estimate – this estimate) for the Oregon bottom trawl fishery. Dark circles represent positive differences and open circles represent negative differences. The largest circle represents approximately difference of 0.04.

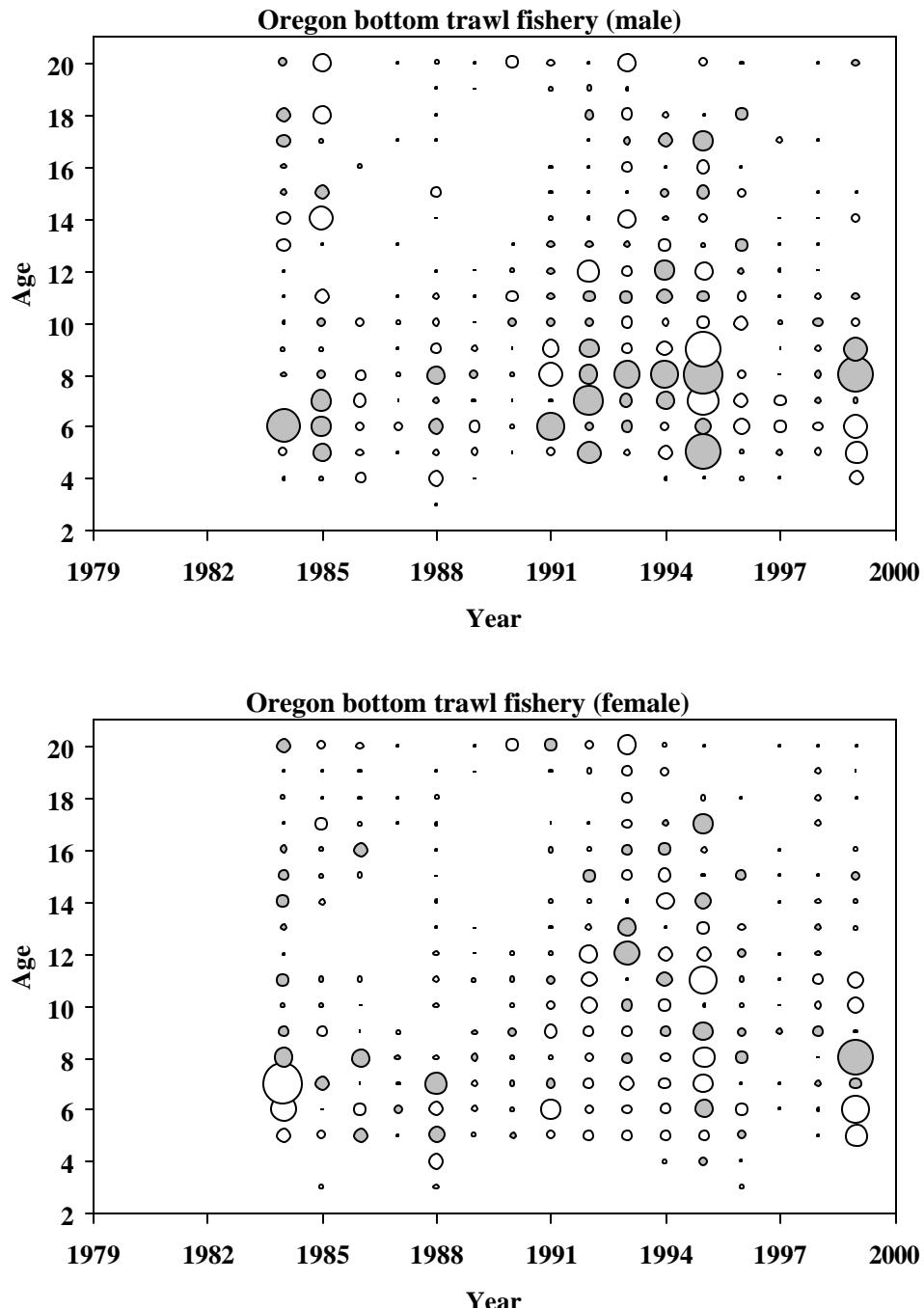


Figure 11. Differences in proportions between age composition data used in 2000 and this assessment (2000 estimate – this estimate) for the Eureka-Conception fishery. Dark circles represent positive differences and open circles represent negative differences. The largest circle represents approximately difference of 0.04.

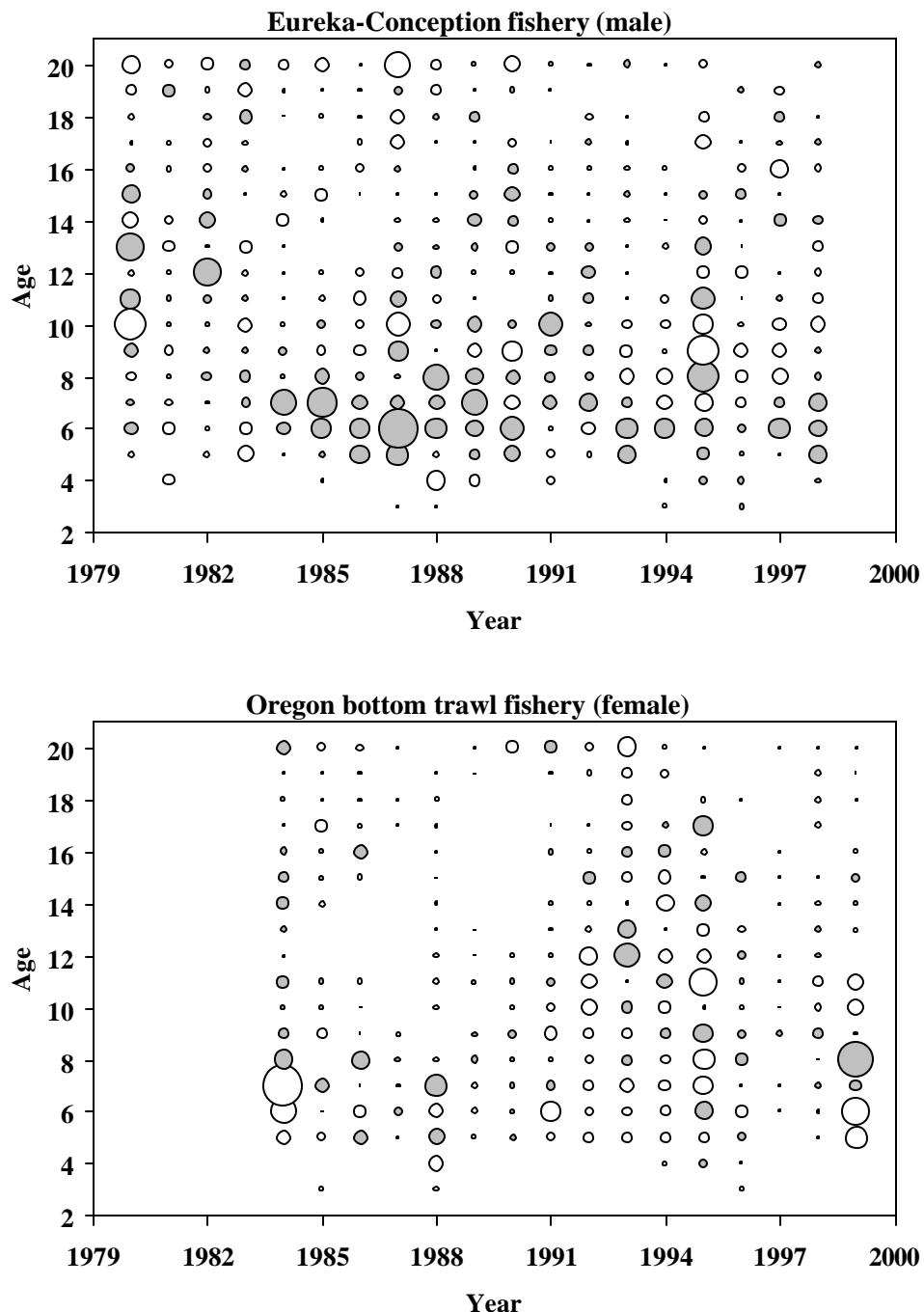


Figure 12. Yearly index estimates from the Santa Cruz/Tiburon Laboratory midwater juvenile trawl survey from 1984 to 2002.

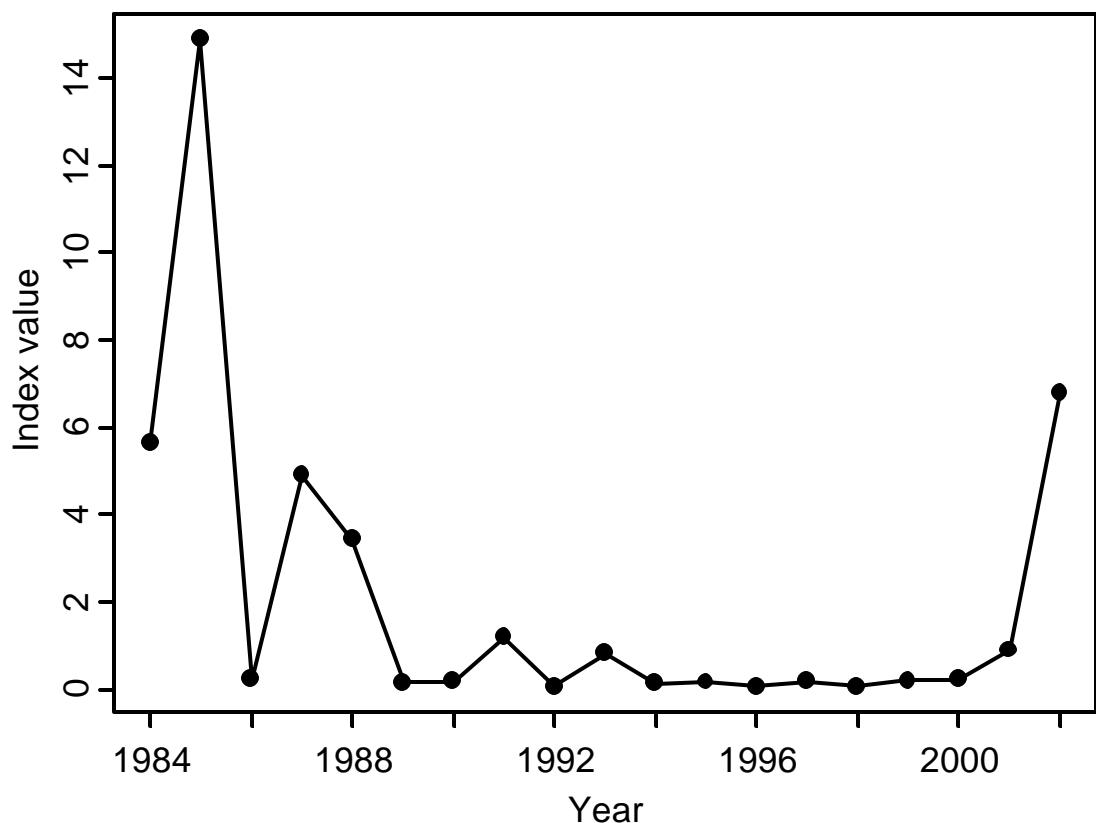


Figure 13. Catch per unit effort of widow rockfish from Oregon bottom trawl fishery from 1984 to 1999.

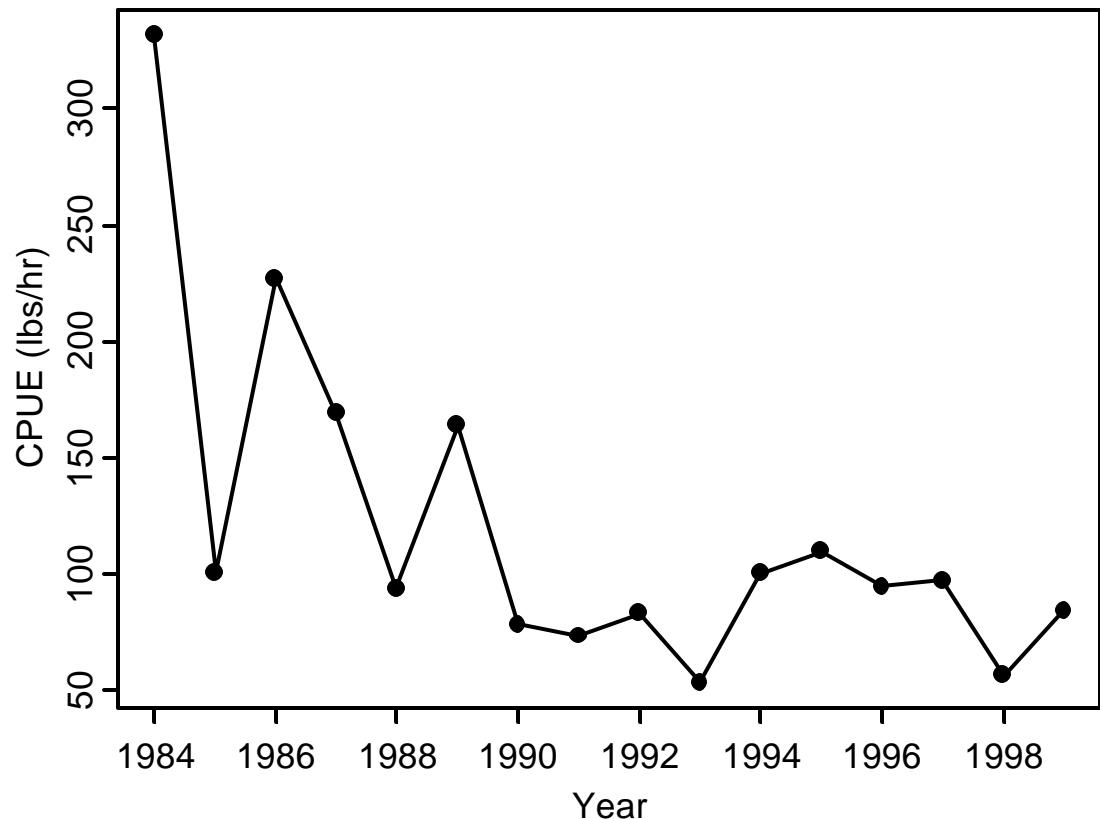


Figure 14. Catch per unit effort of widow rockfish abundance derived from bycatch in the Pacific whiting fisheries.

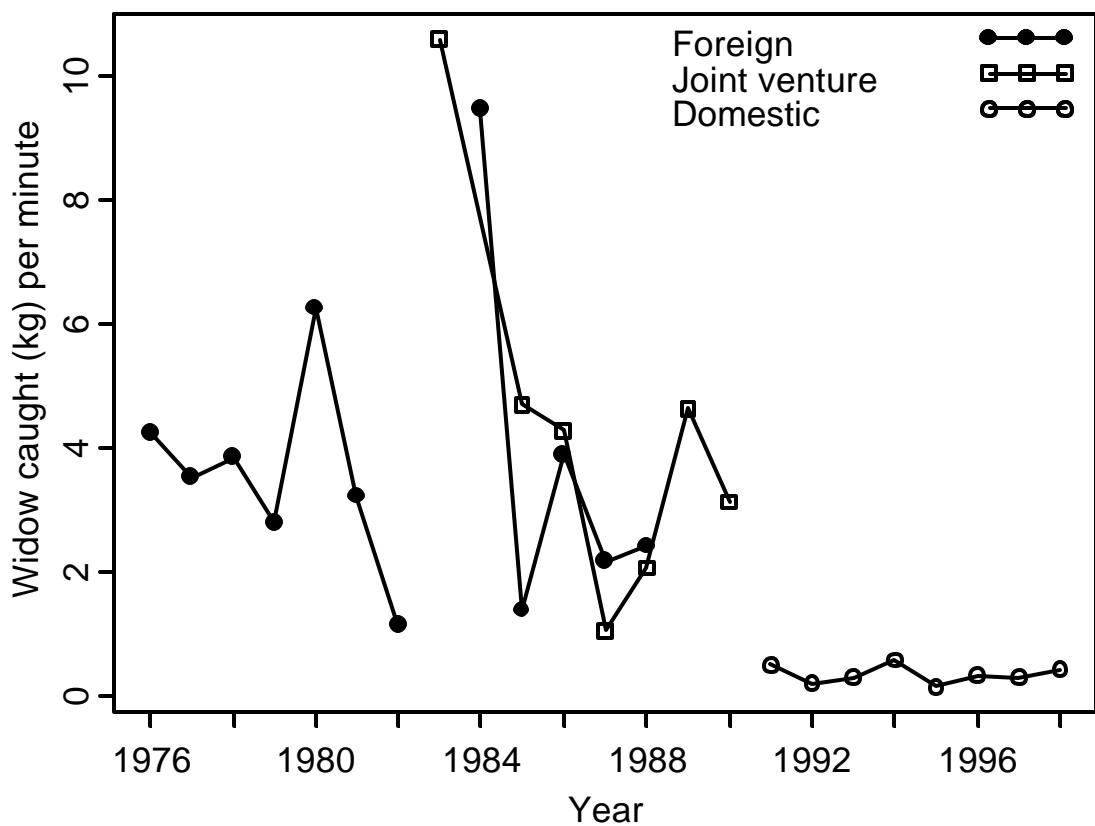


Figure 15. Fraction of landings in the north area, defined as the Vancouver-Columbia and Oregon trawl fisheries, with a 7-year moving average. Note that the fractions before 1977 were fixed at the value computed before the foreign landings (Rogers 2003) were added.

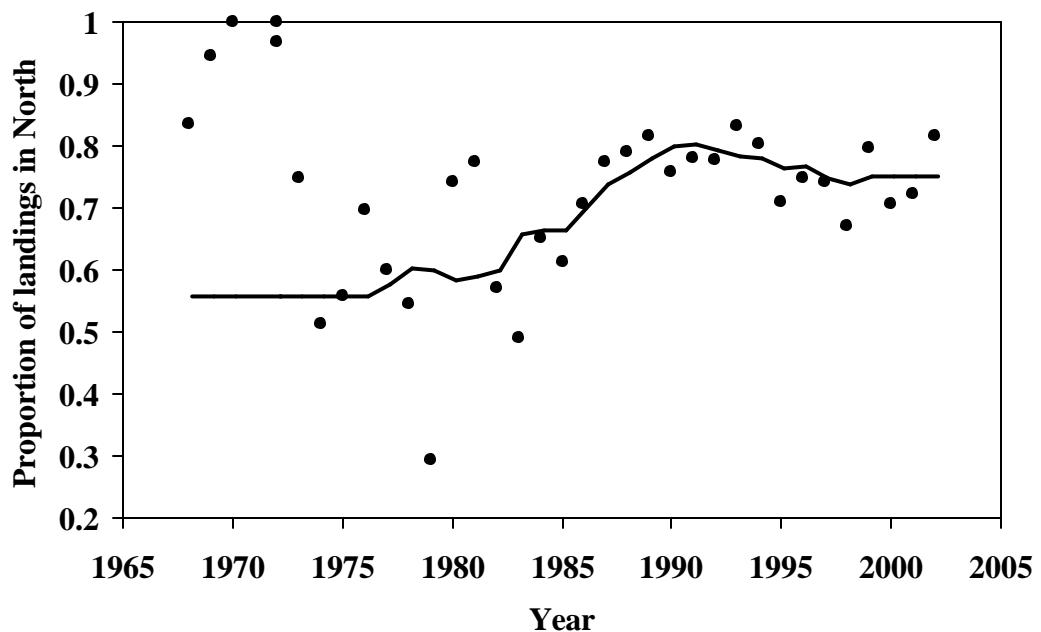


Figure 16. Negative log-likelihood values and percentages of  $B_{2002}$  (spawning output in 2002) over  $B_0$  (spawning output in 1958) from 488 base model runs. These runs were from a total of 500 model runs, of which 12 runs resulted in poor fits of the model (extreme likelihood values or Hessian matrix not positive definite). In each of 500 runs, initial value of every parameter was randomly perturbed by 50% of the best fitted value in the base model.

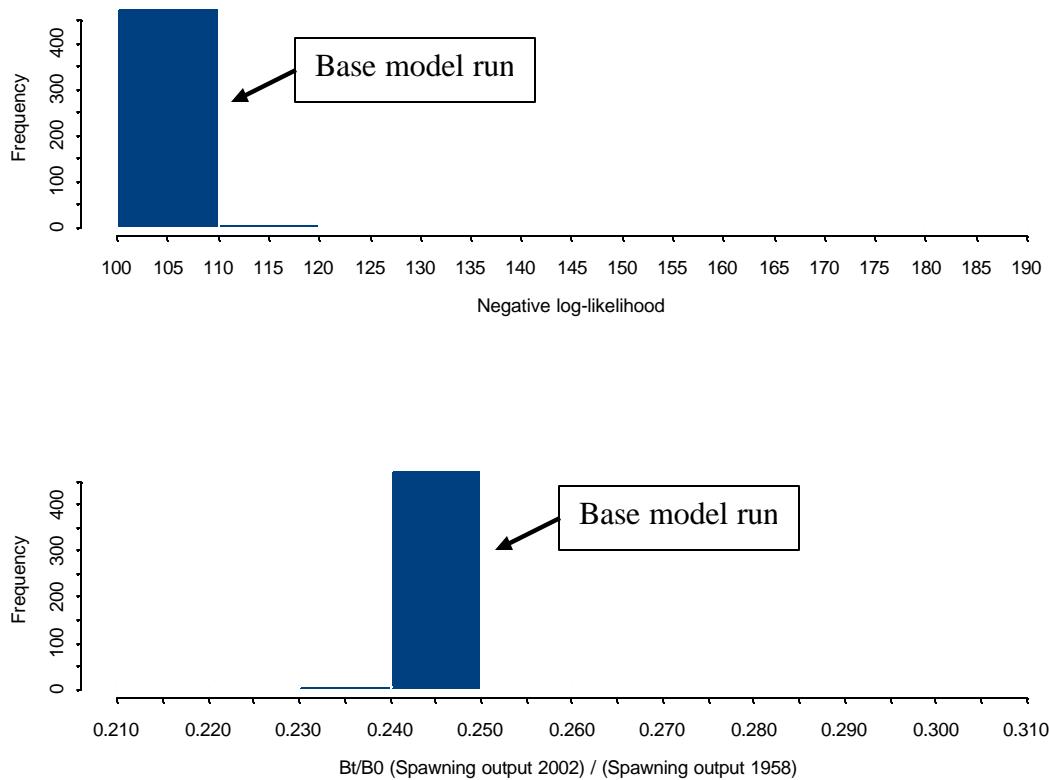


Figure 17. Age 3+ biomass (1000mt) and spawning biomass (1000mt) from 1958 to 2002 estimates from the base model.

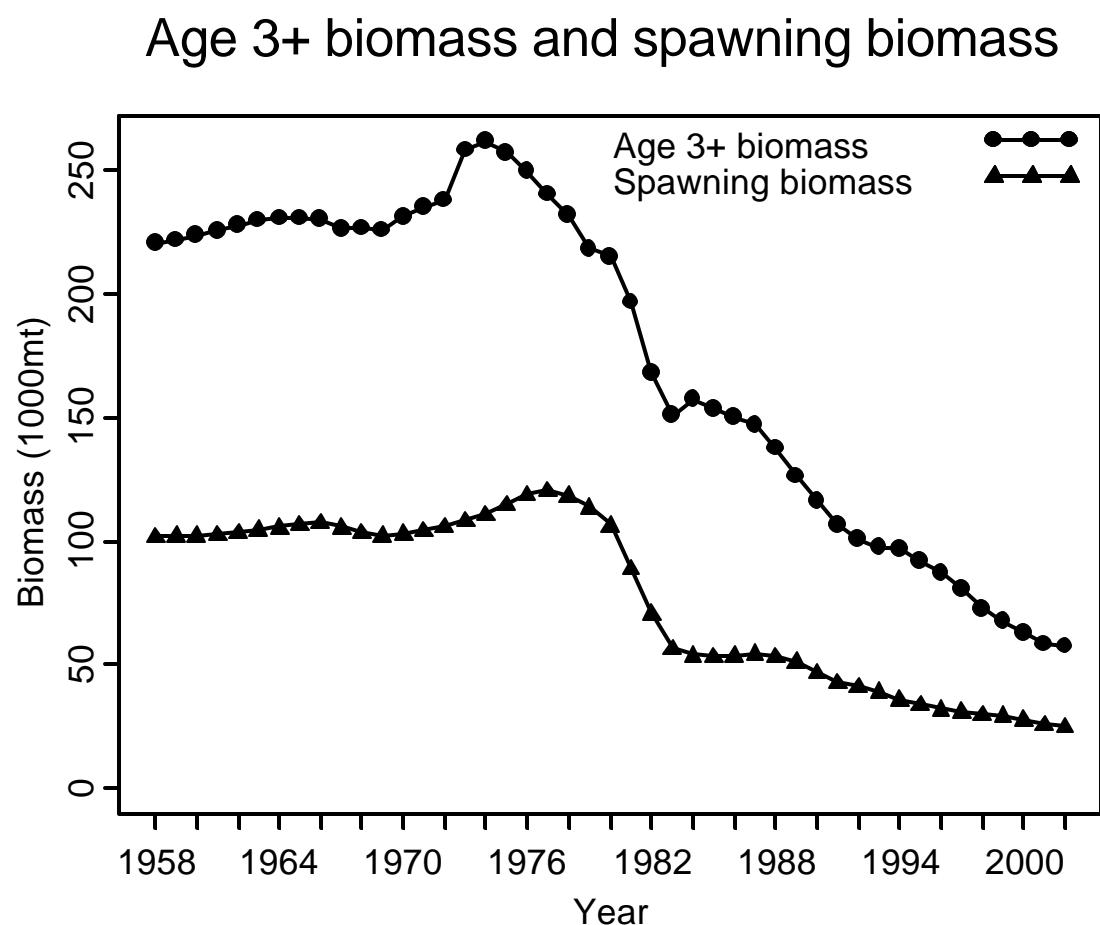


Figure 18. Spawning biomass (million of eggs) from 1958 to 2002, estimates from the base model.

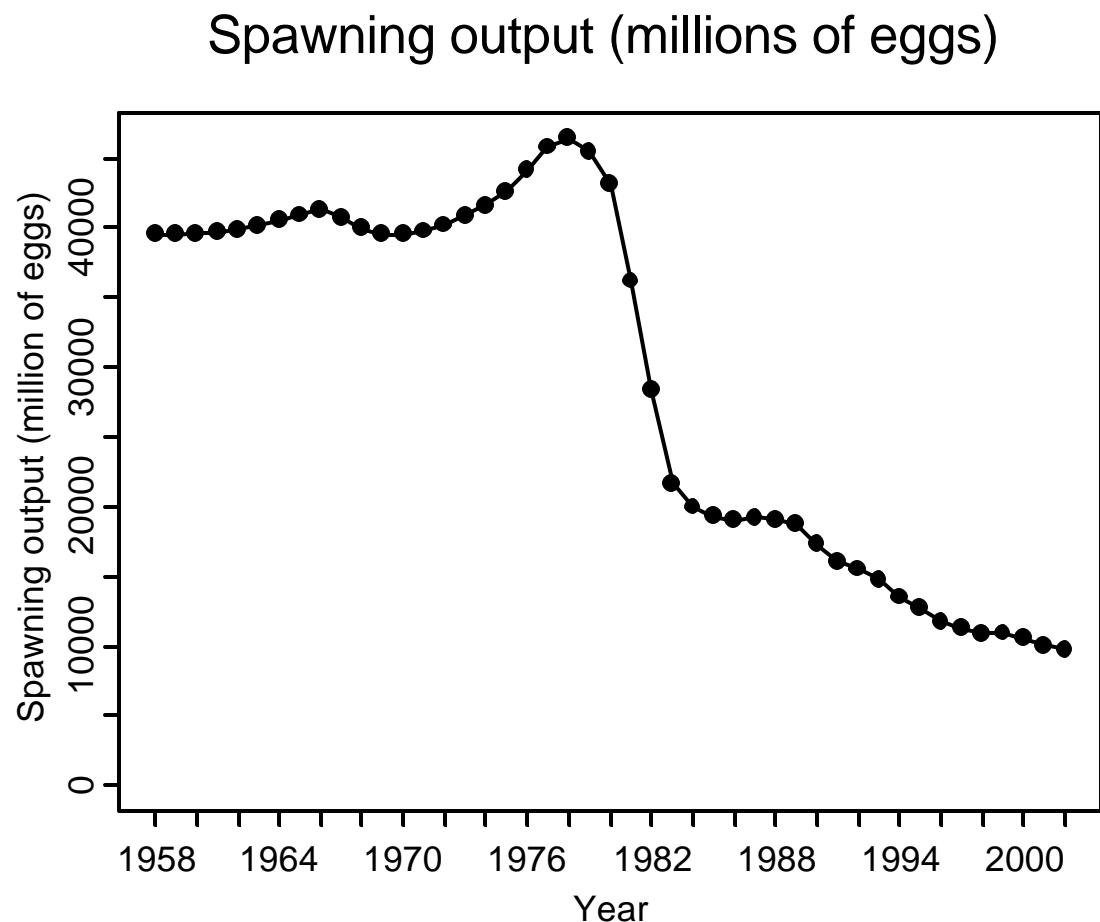


Figure 19. Age 3 recruits (\*1000) from 1958 to 2002 estimates from the base model.

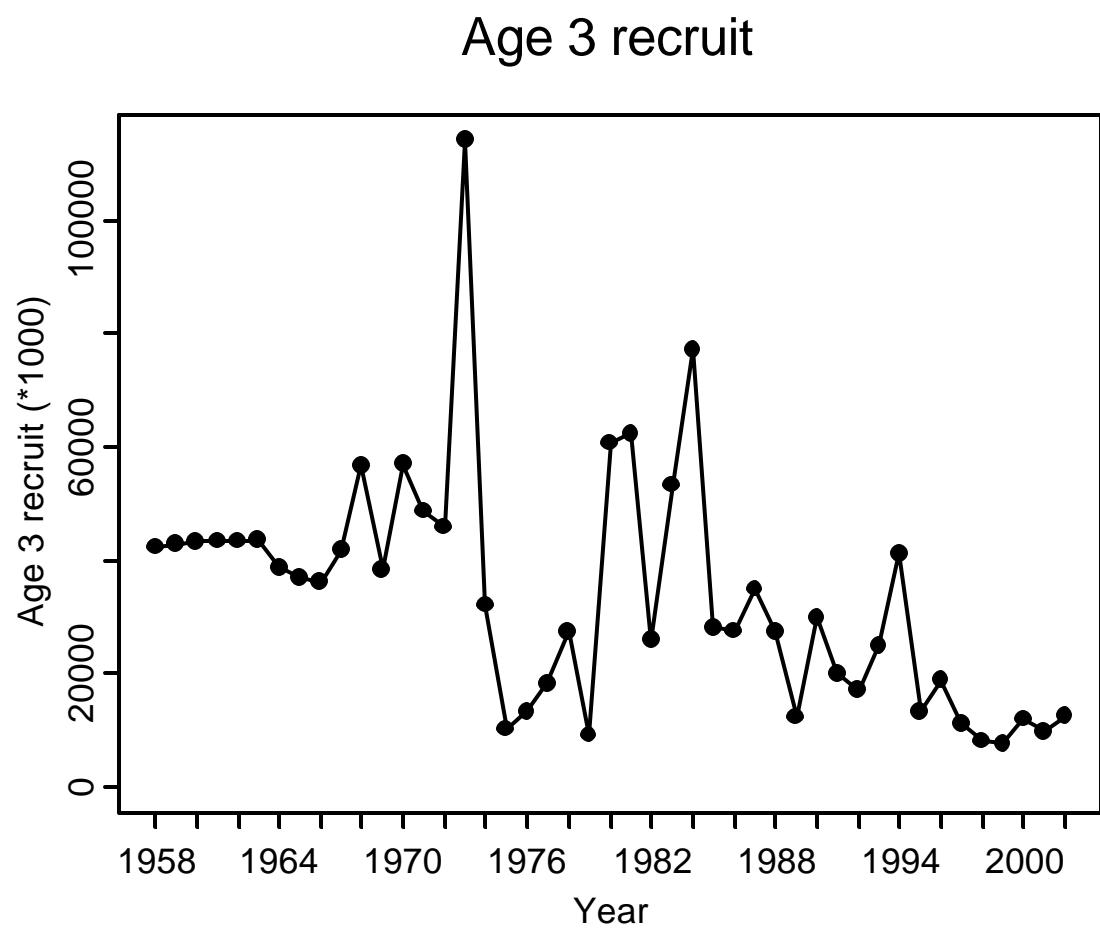


Figure 20. Fishing mortality by four fisheries from 1958 to 2002 estimates from the base model

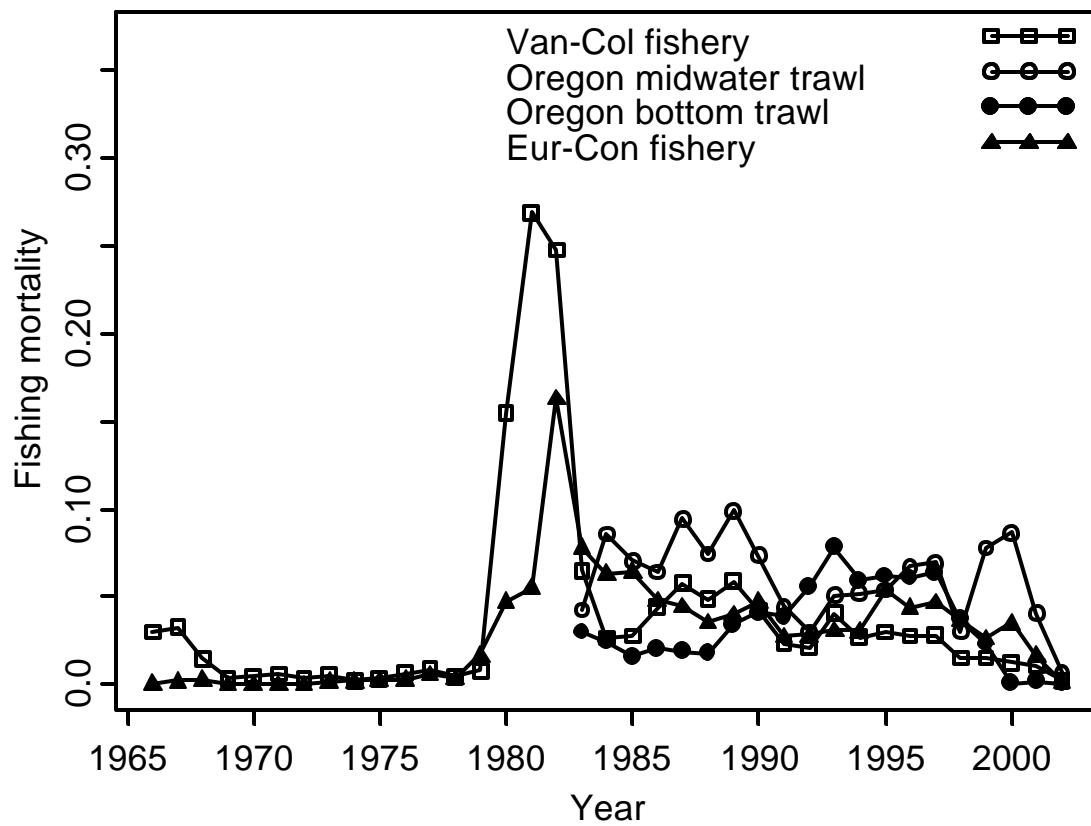


Figure 21. Fishery-specific selectivity estimates from the base model.

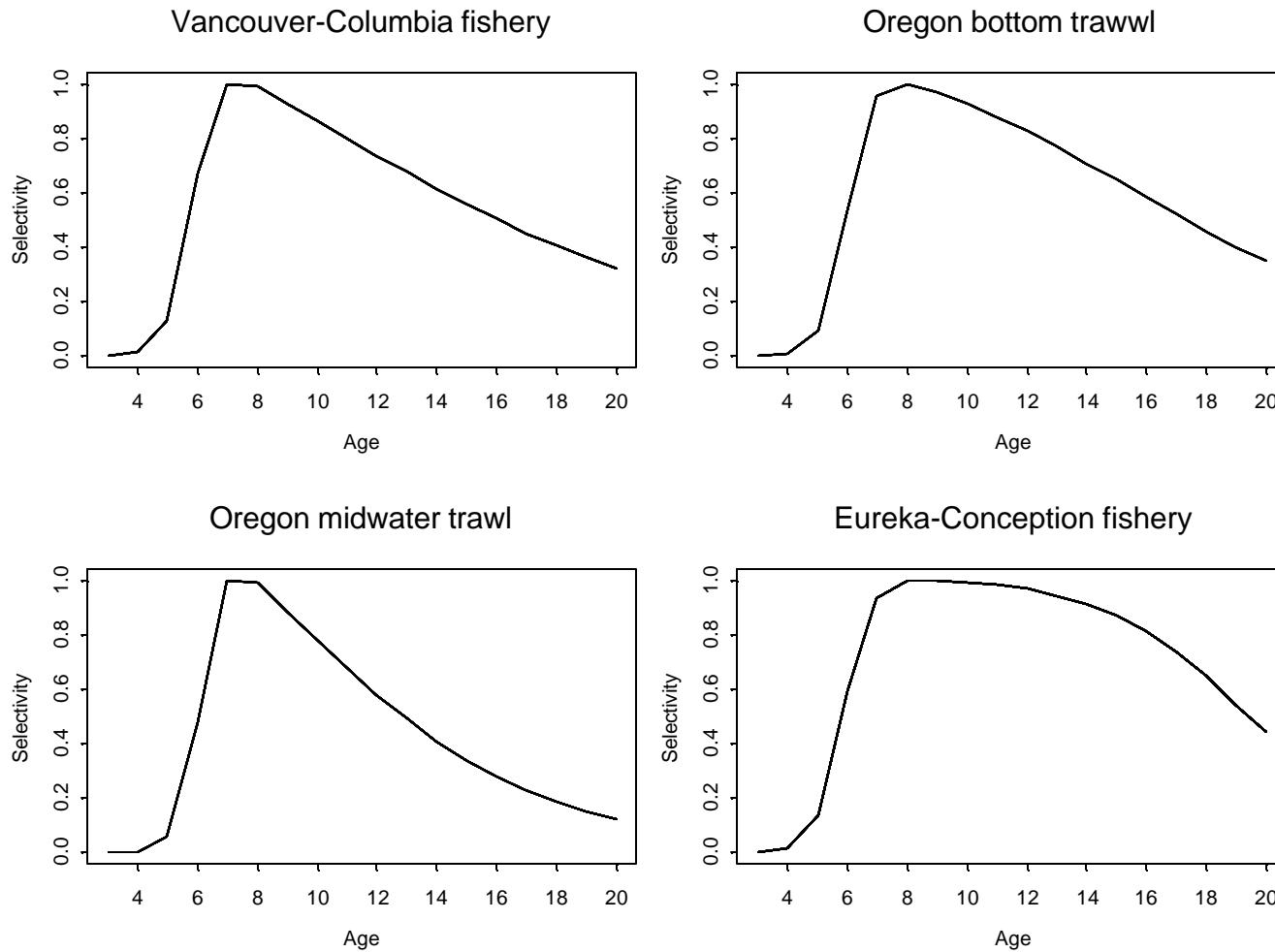


Figure 22. Stock-recruitment relationship from the base model. Est = estimated values from stock-recruitment relationship; Est+Res = predicted values plus annual recruitment residuals.

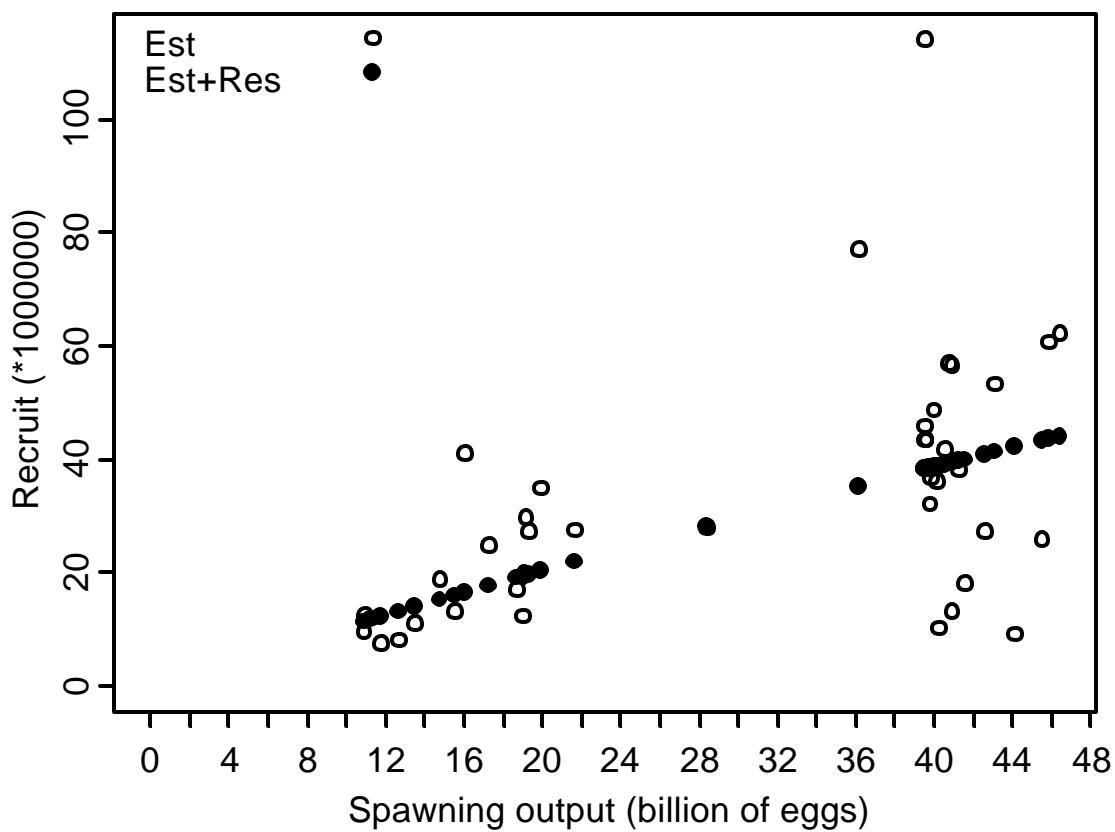


Figure 23. Model fits to the Vancouver-Columbia and Oregon midwater trawl fisheries landings data.

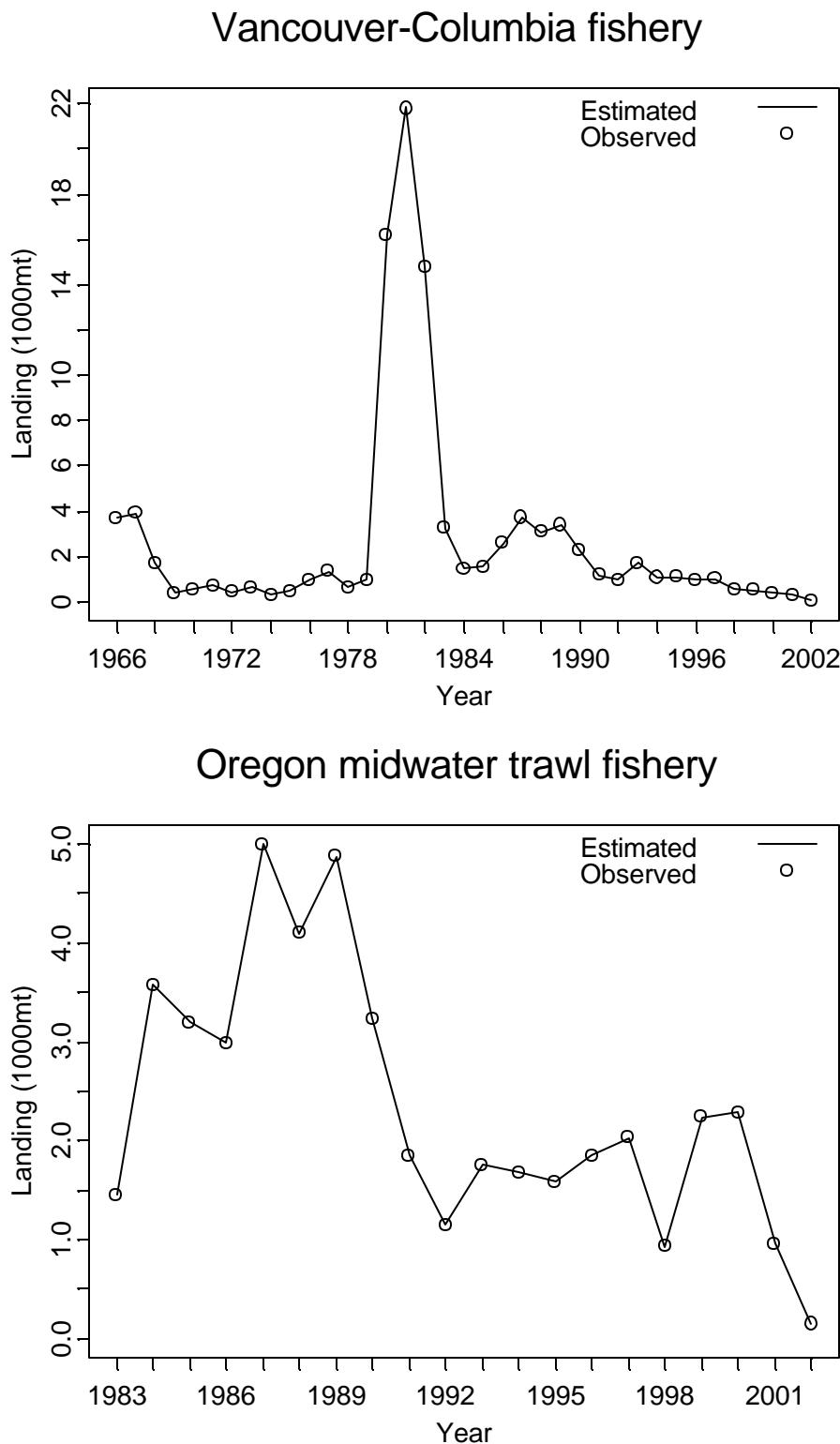


Figure 24. Model fits to the Oregon bottom trawl and Eureka-Conception fisheries landings data.

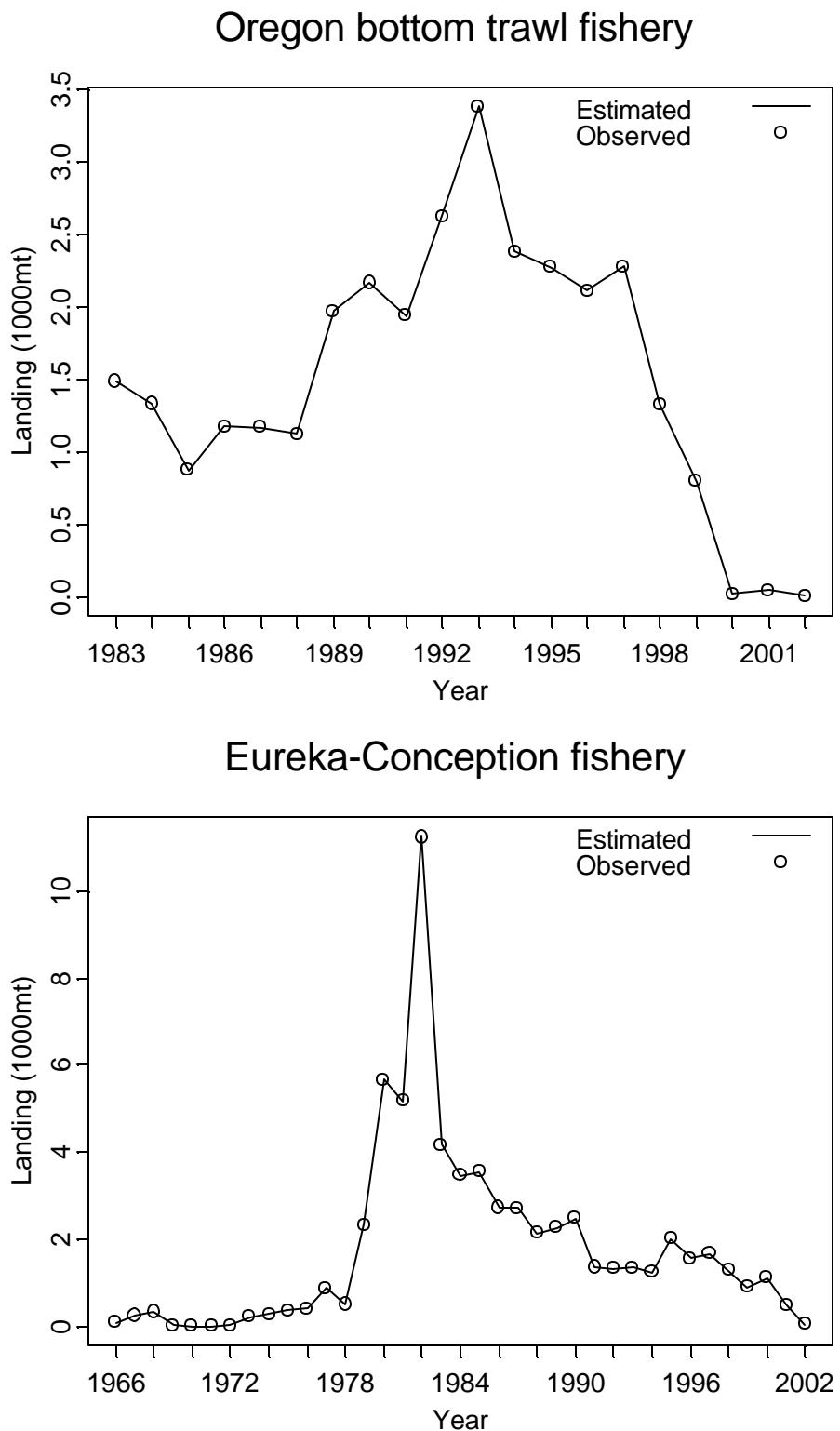


Figure 25. Model fits to the midwater trawl juvenile survey index.

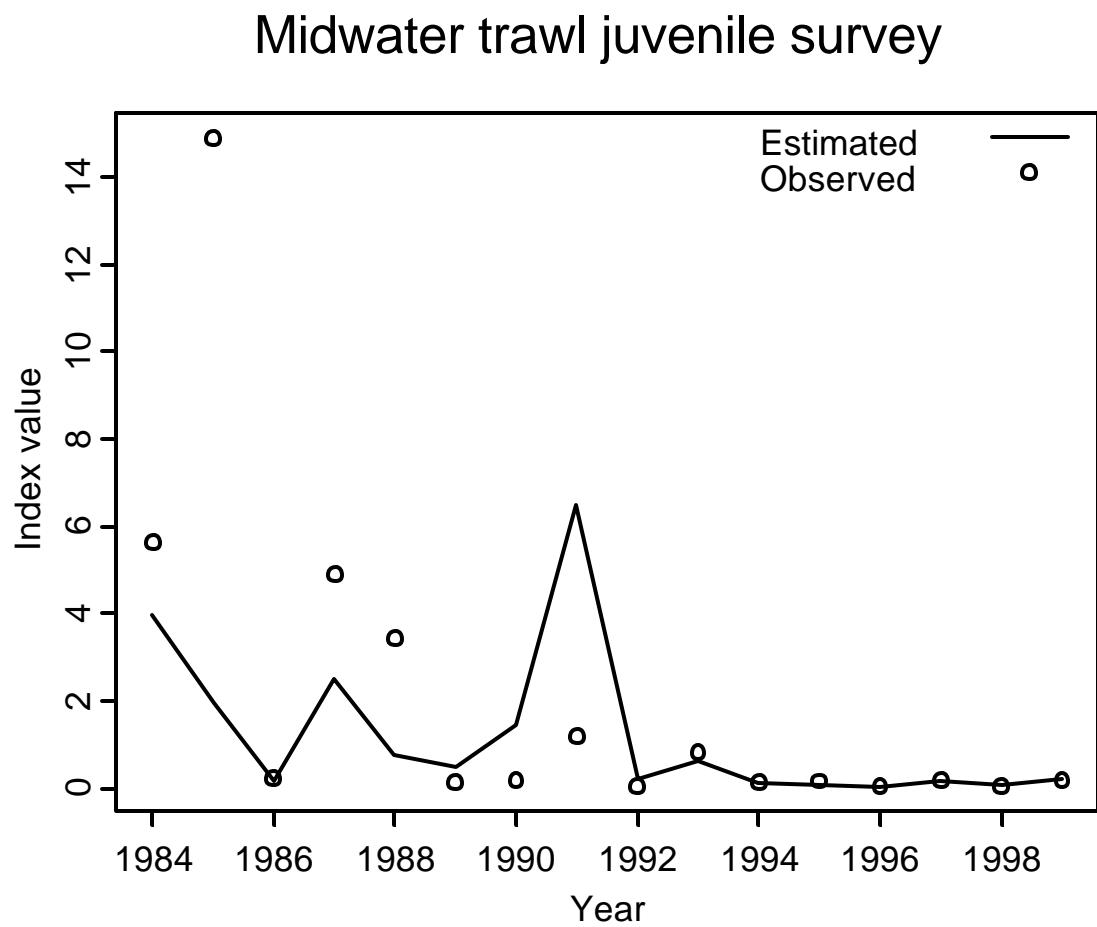


Figure 26. Model fits to the Oregon bottom trawl logbook index.

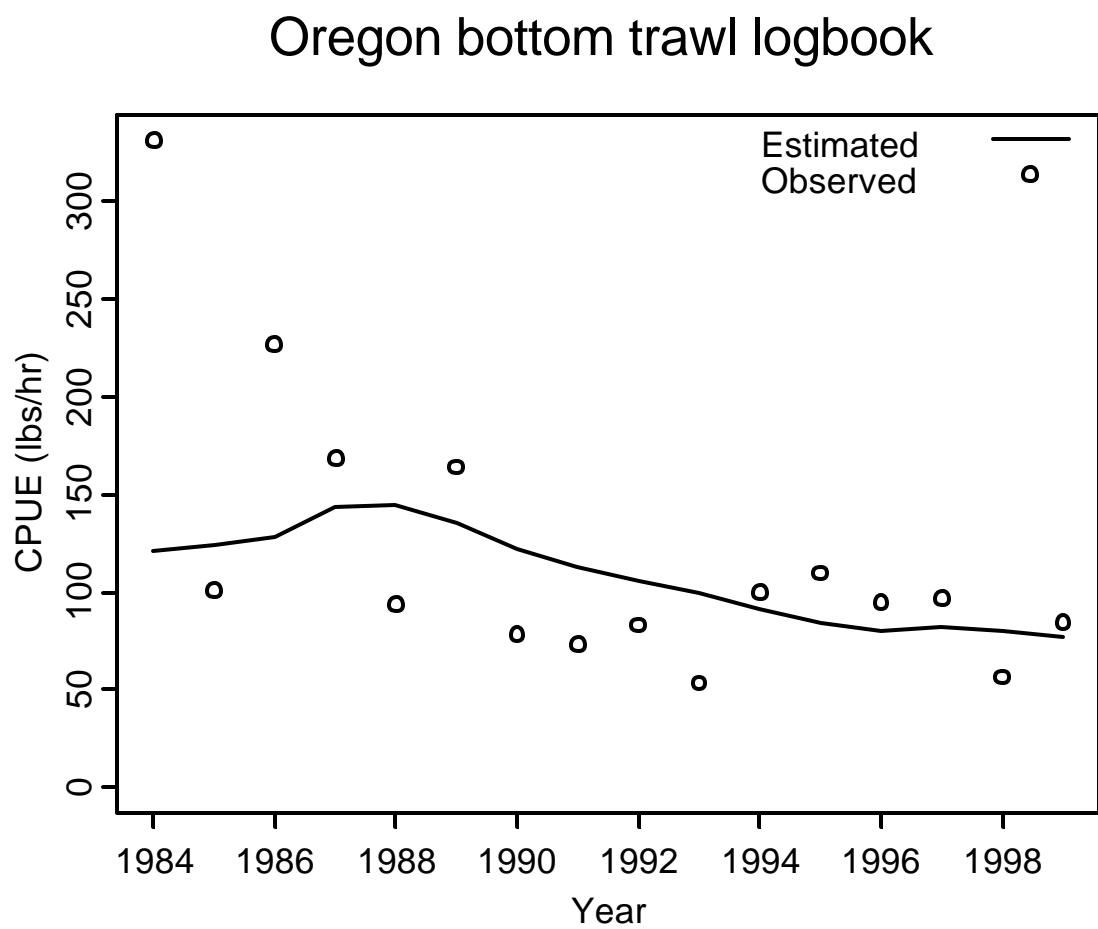


Figure 27. Model fits to the Pacific whiting foreign fishery bycatch index.

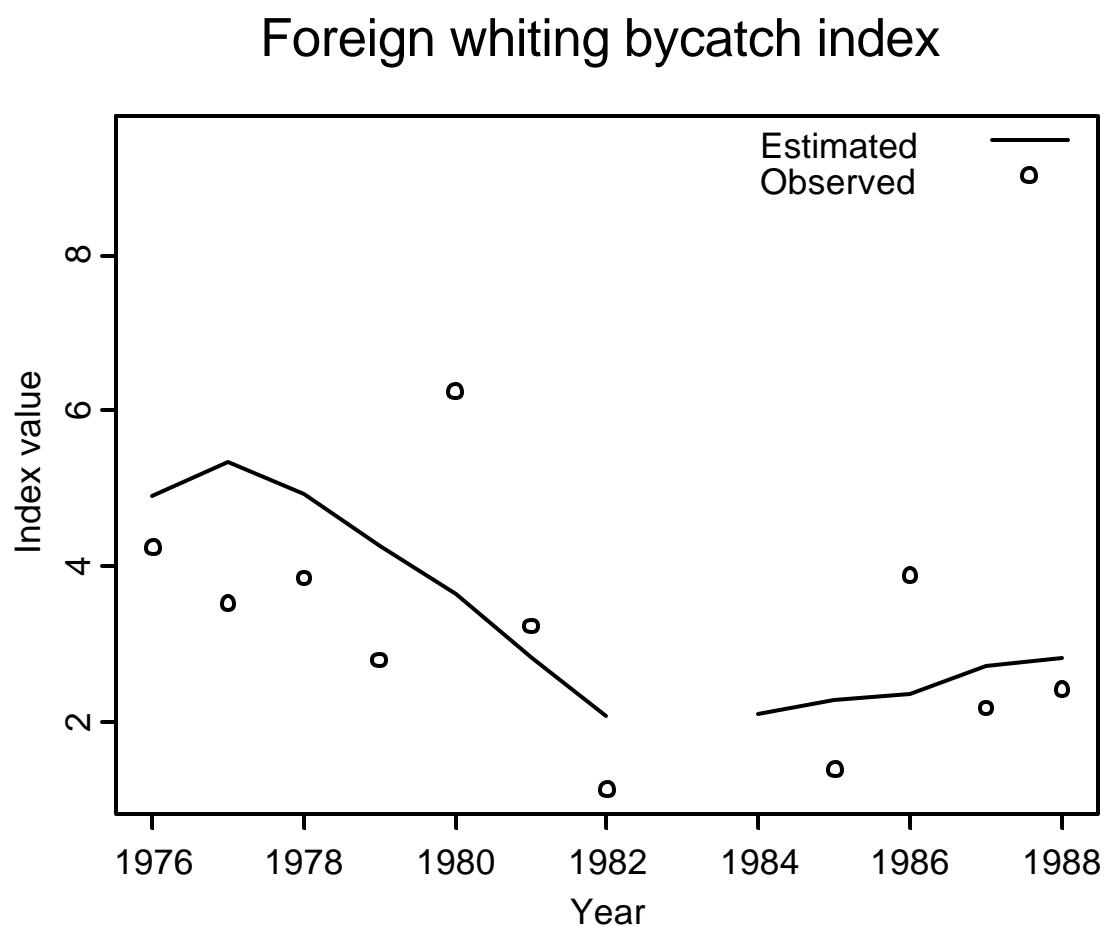


Figure 28. Model fits to the Pacific whiting joint venture fishery bycatch index.

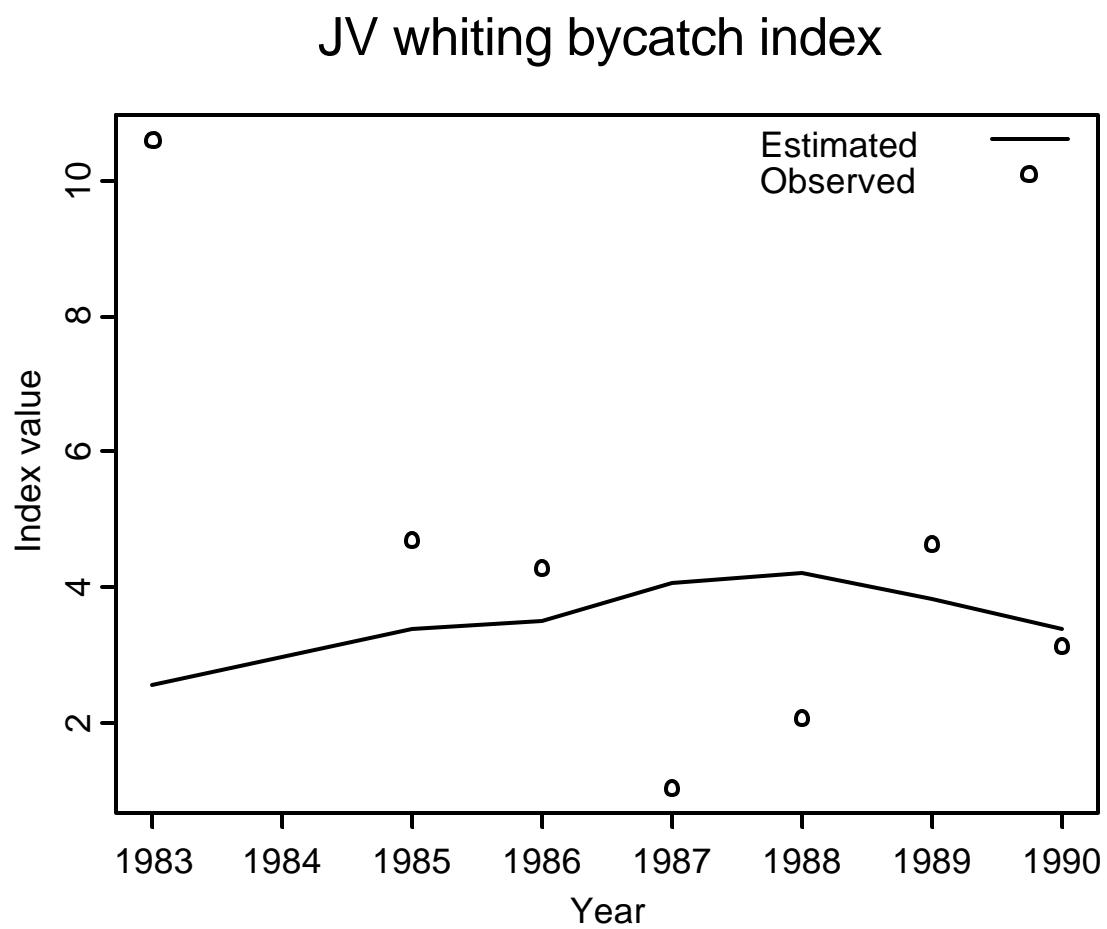


Figure 29. Model fits to the Pacific whiting domestic fishery index.

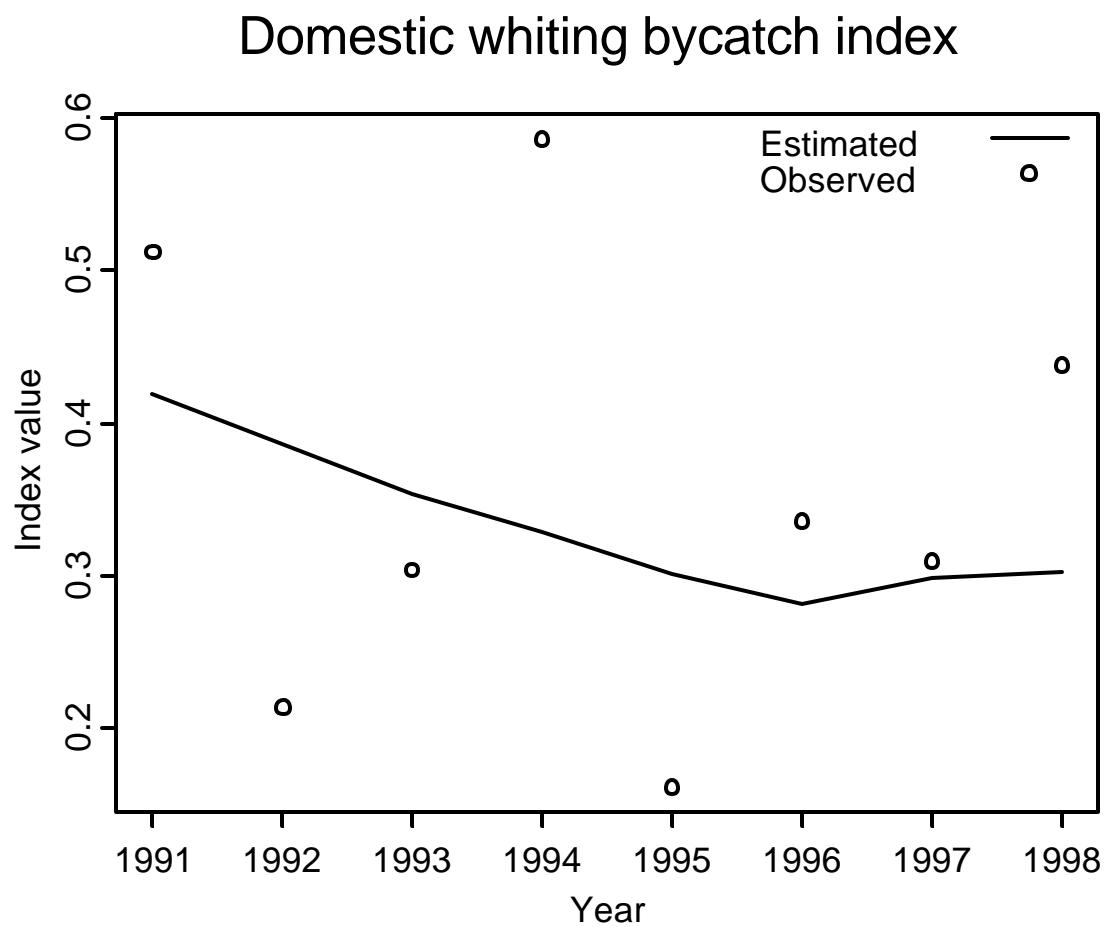


Figure 30a. Age composition residuals for the Vancouver-Columbia fishery from the base model. Residuals are standardized differences (observed – estimated). Dark circles are positive residuals and open circles are negative residuals.

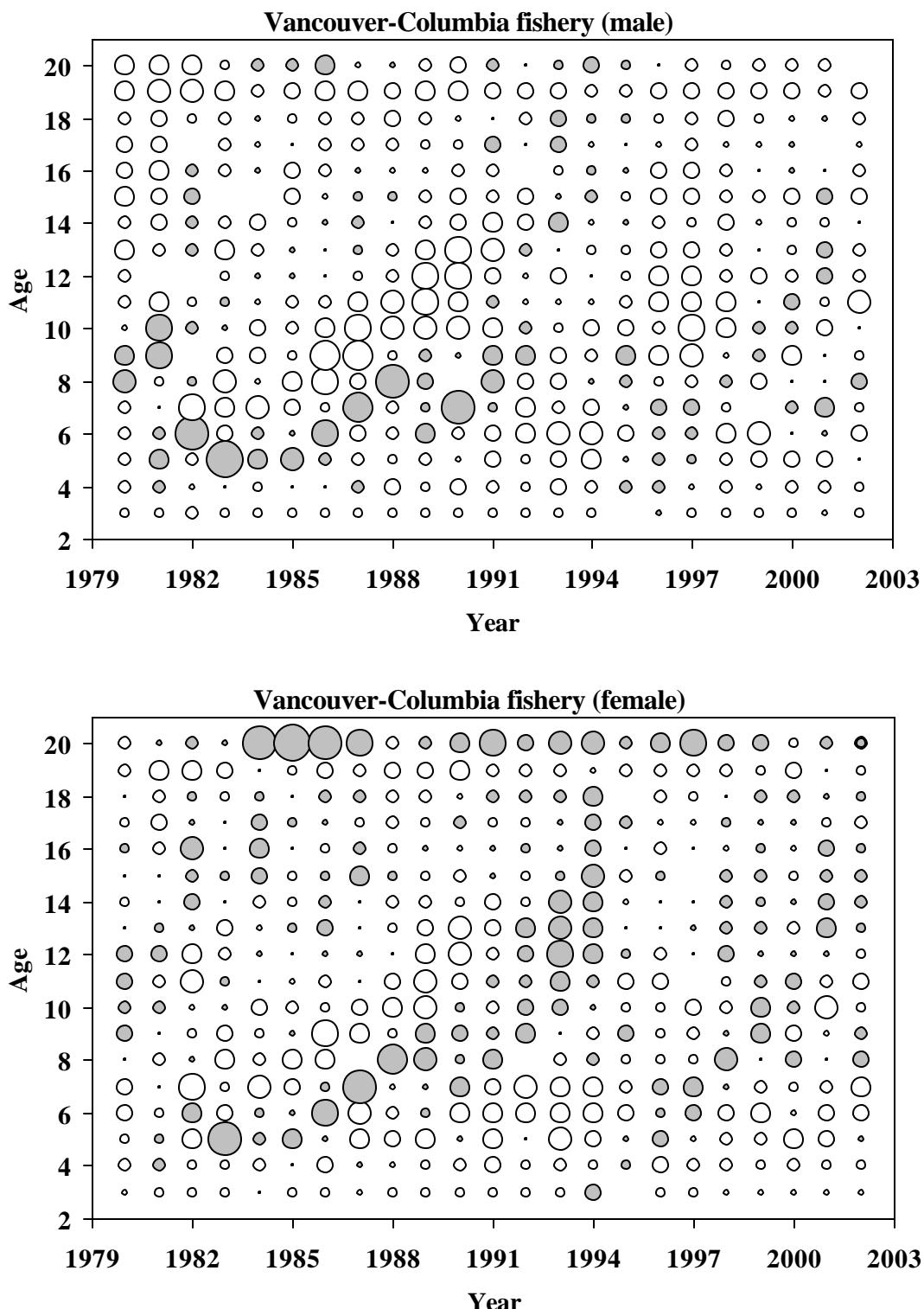


Figure 30b. Age composition residuals for the Oregon midwater trawl fishery from the base model. Residuals are standardized differences (observed – estimated). Dark circles are positive residuals and open circles are negative residuals.

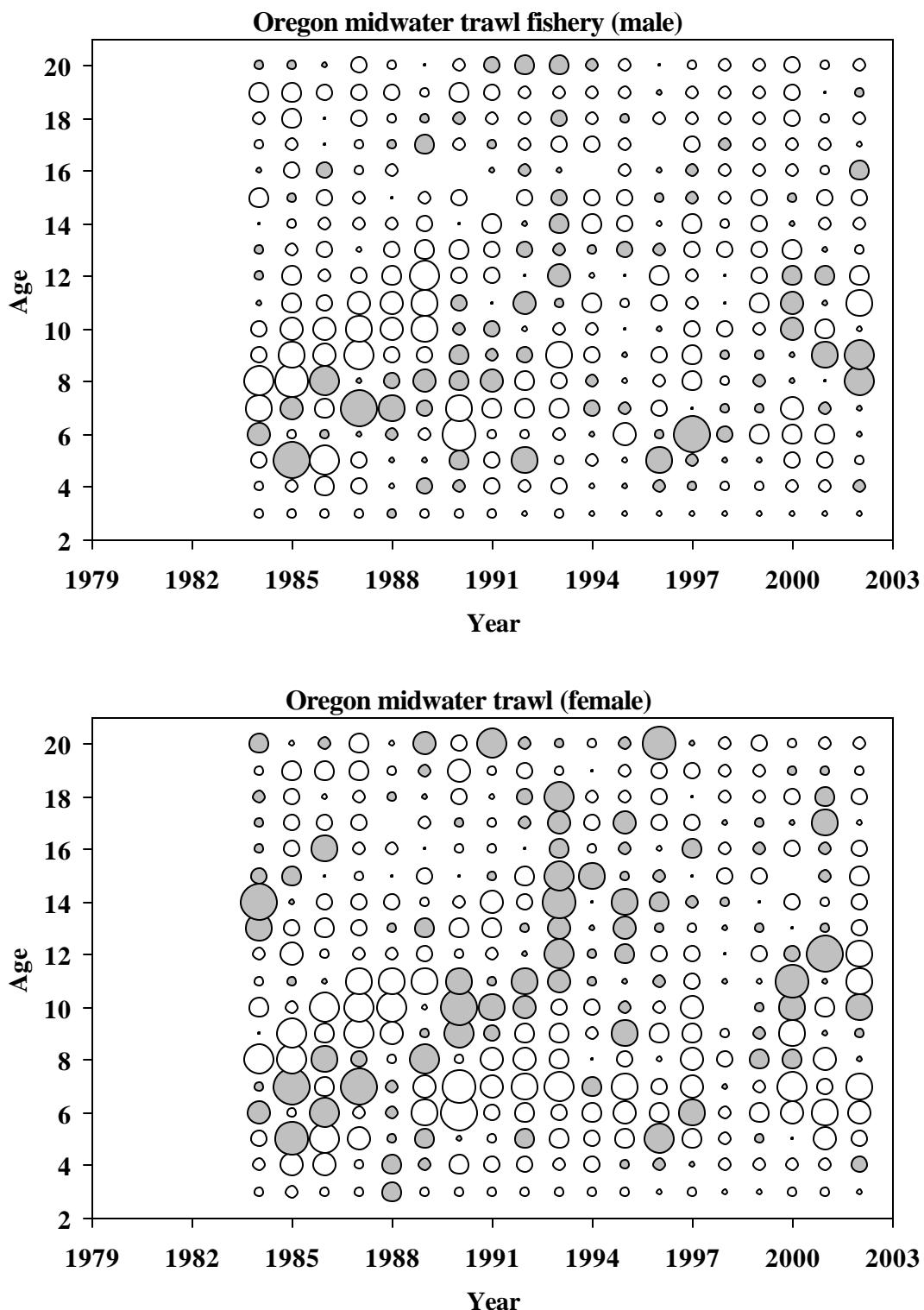


Figure 30c. Age composition residuals for the Oregon bottom trawl fishery from the base model. Residuals are standardized differences (observed – estimated). Dark circles are positive residuals and open circles are negative residuals.

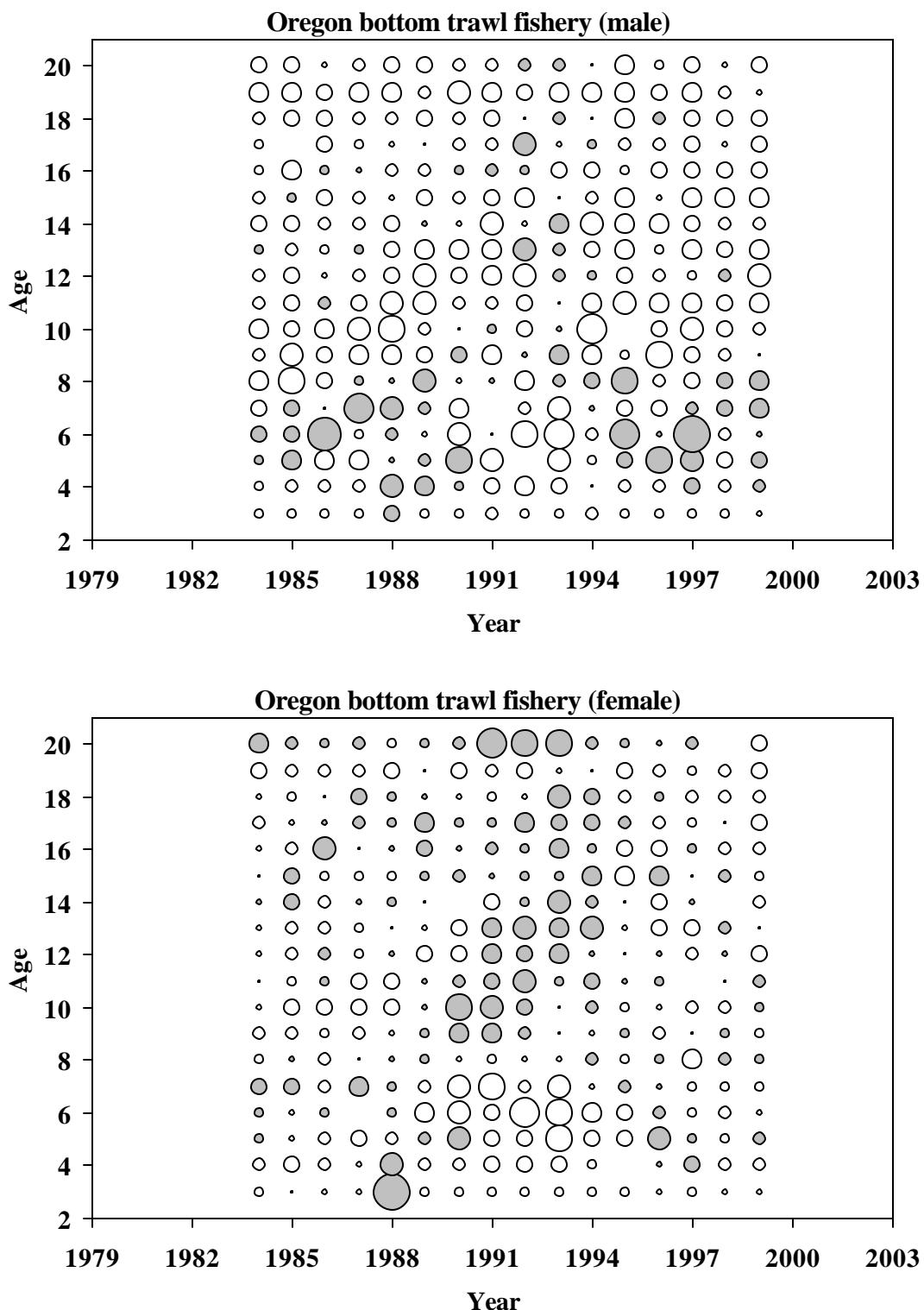


Figure 30d. Age composition residuals for the Eureka-Conception fishery from the base model. Residuals are standardized differences (observed – estimated). Dark circles are positive residuals and open circles are negative residuals.

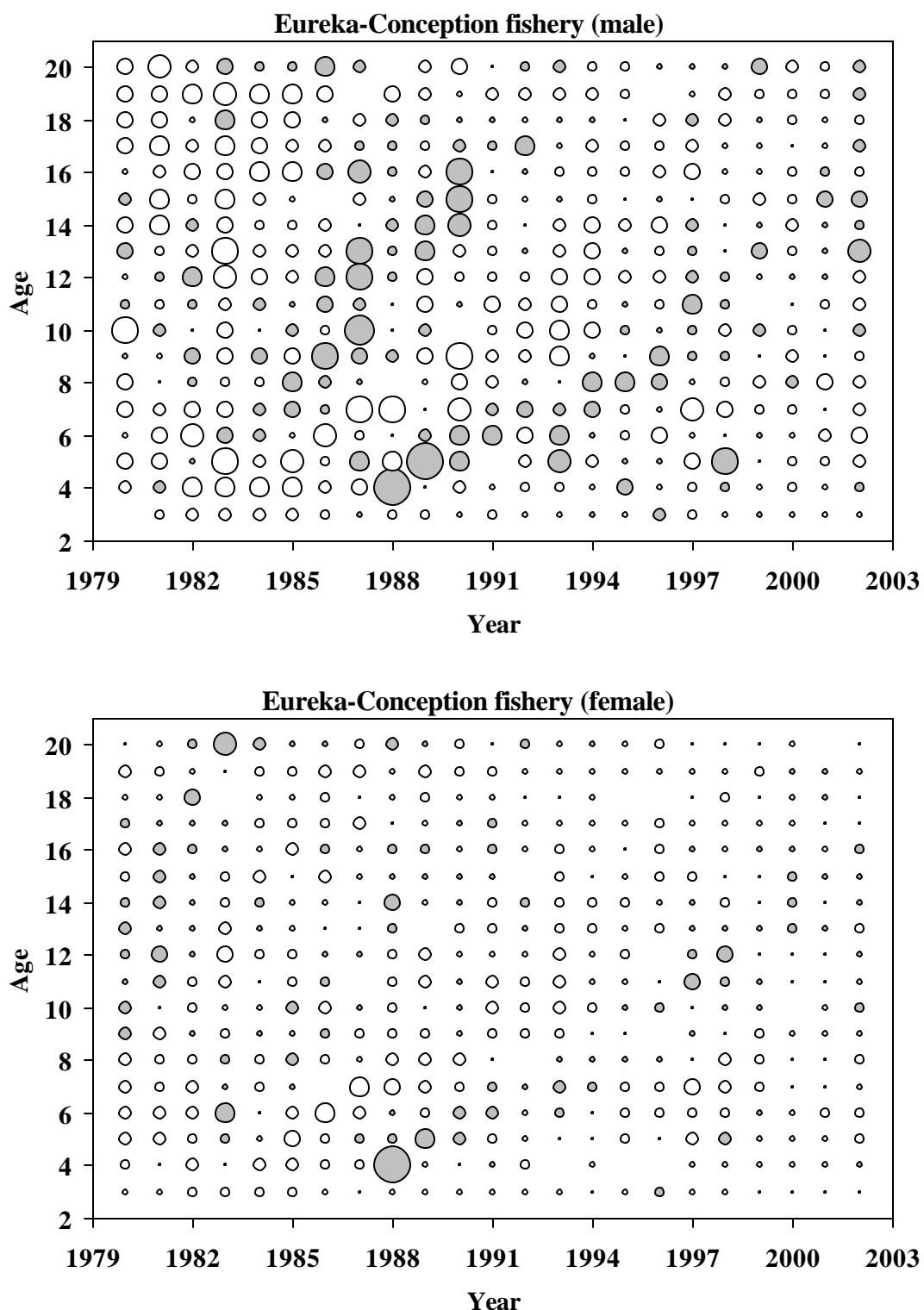


Figure 31. Retrospective analysis of the model showing spawning outputs from the model runs with the most recent data removed. Run to 2002 = no data removed; Run to 2001 = data from 2002 removed; Run to 1999 = data from 2000 to 2002 removed; and Run to 1997 = data from 1998 to 2002 removed.

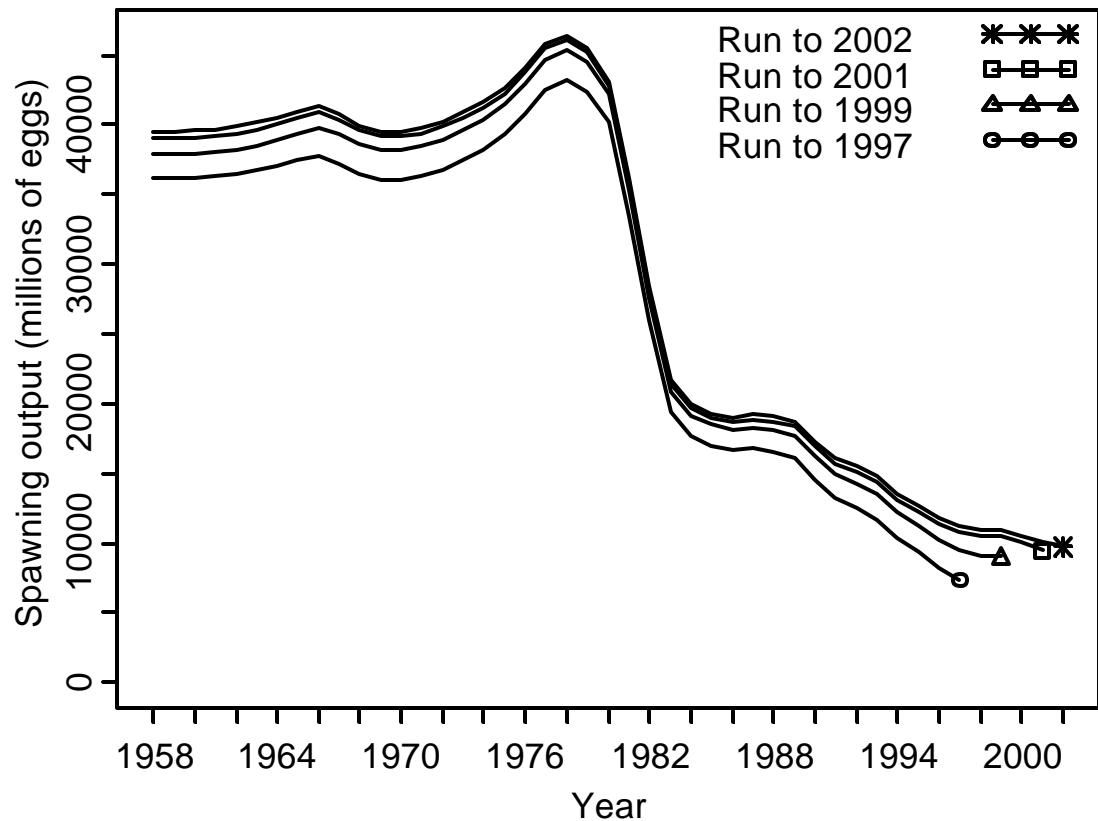


Figure 32. Frequency distribution on percentages of  $B_{2002}$  (spawning output in 2002) over  $B_0$  (spawning output in 1958). Both  $B_{2002}$  and  $B_0$  are outputs from the last 2 million runs of a total of 3 million MCMC runs.

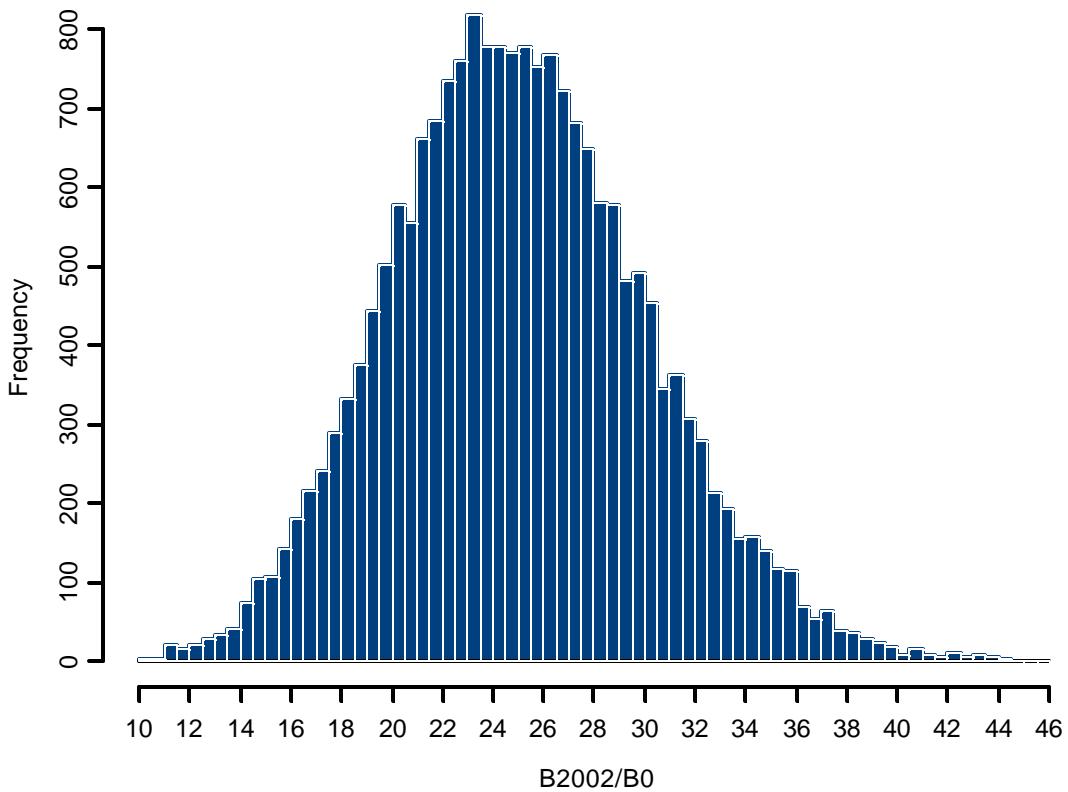


Figure 33. Median of spawning outputs ( $10^6$  eggs) from 1958 to 2002 estimates from the widow rockfish model. Dotted lines indicate 95% confidence intervals. The medians and confidence intervals are computed from the last 2 million runs in a total of 3 million MCMC runs.

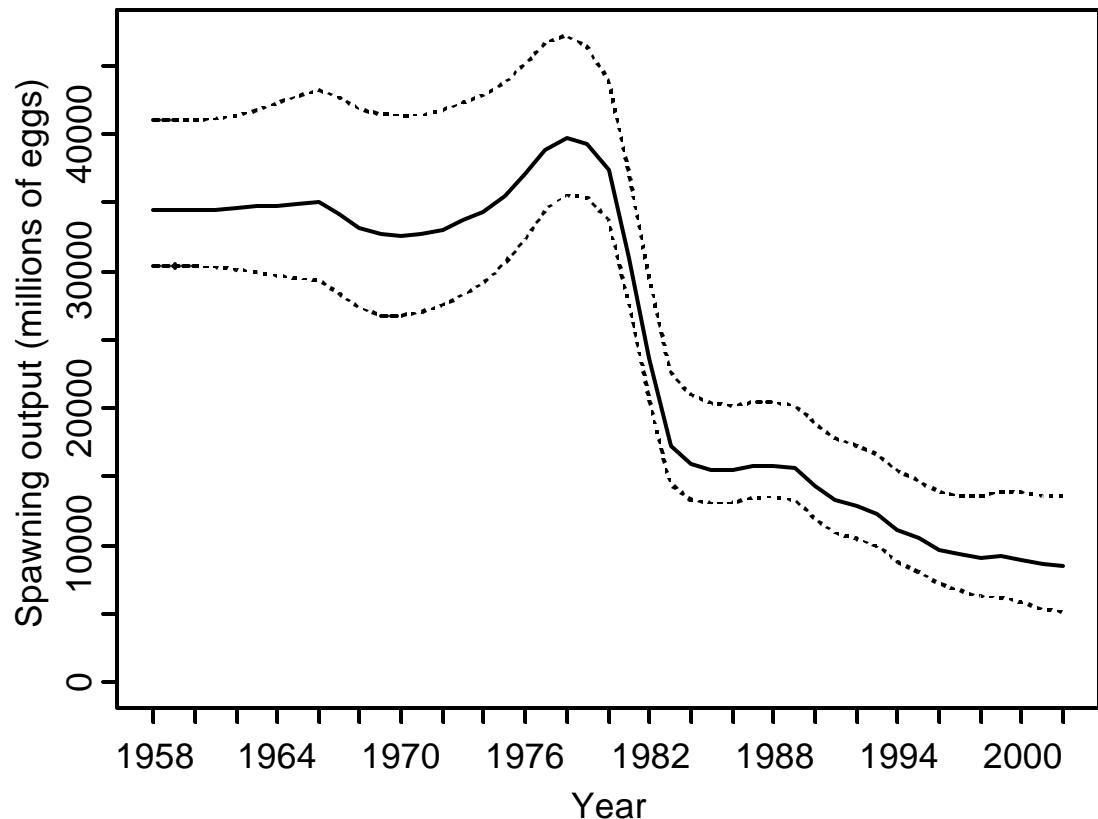
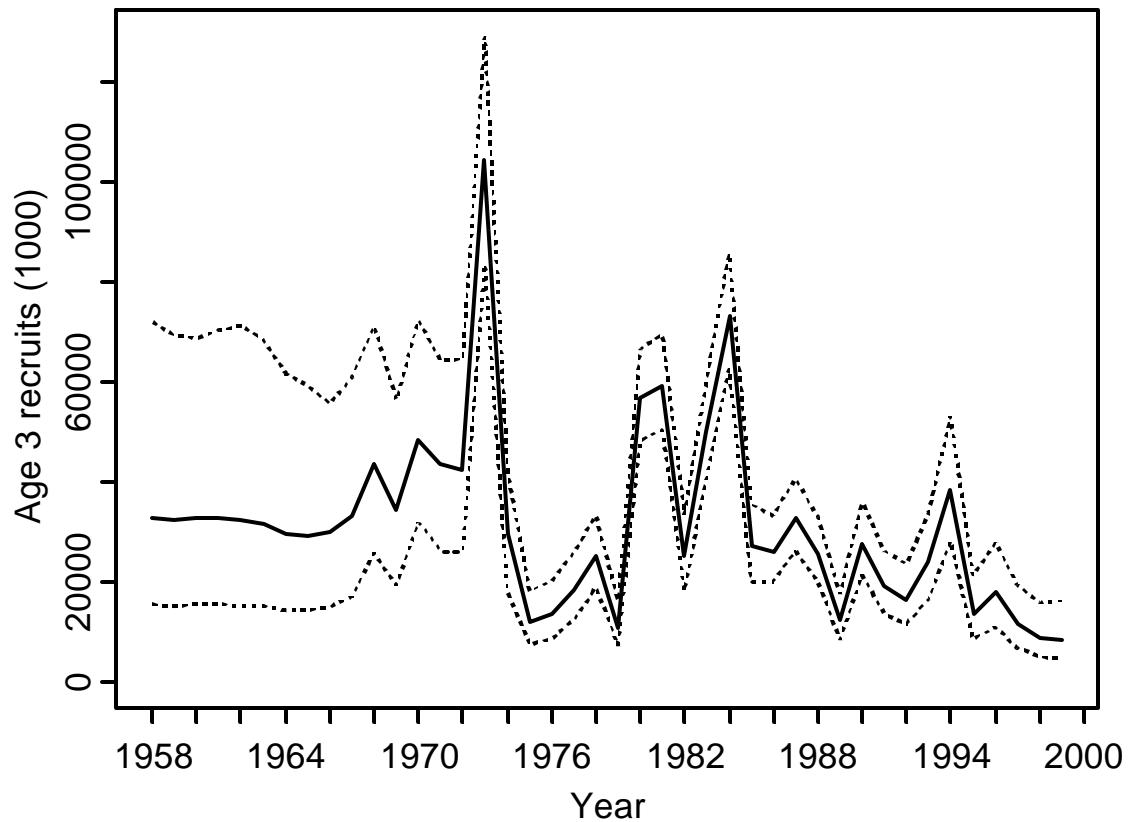


Figure 34. Recruitment estimates from 1958 to 2002 from the base model. Dotted lines indicate 95% confidence intervals. The confidence intervals are computed from the last 2 million runs in a total of 3 million MCMC runs.



## Appendix A. Three widow bycatch indices computed from the Pacific Hake fisheries

E.J. Dick, Xi He, and Steve Ralston  
NMFS, Southwest Fisheries Science Center, Santa Cruz Laboratory

We computed three abundance indices based on incidental catch of widow rockfish in the Pacific Hake fishery. As in the previous assessment (Williams et al., 2000), we recognized three periods of the fishery and treated them as independent indices in the model: ‘foreign’ (1976-88), ‘joint-venture’ (1983-90), and ‘domestic’ (1991-2001). Data for the domestic fishery were obtained from the NORPAC database, and Martin Dorn (AFSC) supplied data for the foreign and joint-venture fisheries.

We excluded records with extreme and/or missing values prior to calculating each index. Table A1 describes the final data sets for each fishery.

Table A1. Summary of three Pacific Hake fisheries’ data used in computing bycatch CPUE of widow rockfish.

FIELD	FISHERY		
	Foreign	Joint-Venture (JV)	Domestic
Year	1976-82, 1984-88	1983, 1985-90	1991-2001
Tow duration	>15 min. & <500 min.	>15 min. & <500 min.	>15 min. & <500 min.
Latitude	43° – 46°, 47° – 48°	43° – 49°	43° – 49°
Hake catch	< 50 tons/tow	< 150 tons/tow	< 150 tons/tow
Widow catch	< 5 tons/tow	< 5 tons/tow	< 5 tons/tow
Gear type (NORPAC code)	Pair trawl (4)	Pair trawl (4) Non-pelagic trawl (1)	Pelagic trawl (2)
Standardized CPUE (see text)	<= 2 std. deviations	<= 2 std. deviations	<= 2 std. deviations
Distance from 200m isobath	<= 5 nautical miles	<= 5 nautical miles	<= 5 nautical miles

We calculated CPUE per tow ( $x_i$ ) as the weight of widow rockfish divided by tow duration in minutes. We then calculated a standardized CPUE (‘z-score’) for each record by subtracting year-specific mean CPUE and dividing by the standard deviation in CPUE for that year. Records with z-scores >2 were excluded from the analyses.

$$Z_i = \frac{(x_i - \bar{x}_y)}{s_y}$$

To examine the spatial distribution of hake effort and associated widow catch rates, we generated a 200-meter isobath using bathymetry grids and geographic information system software from ESRI (ArcView v. 3.2). For each tow, we calculated distance in nautical miles from the 200 m isobath, and binned tows into 0.5 nautical mile bands from the isobath. This analysis confirmed that hake effort is centered over the 200-meter depth contour. Mean z-scores for each distance category indicate that widow catch rates are highest near the 200 m isobath, largely tapering off within 5 nautical miles.

The first ‘bycatch index’ ( $I_y^1$ , Index 1) was calculated using a method identical to the previous three assessments (Rogers and Lenarz 1993, Ralston and Pearson 1997, Williams et al. 2000):

$$I_y^1 = \frac{C_y}{F_y} \cdot \frac{\sum_{i=1}^{n_y} w_{iy}}{\sum_{i=1}^{n_y} h_{iy}}$$

where  $n_y$  is the number of tows in year  $y$ . The first component of this index is a ratio of total hake catch by the U.S. fishery,  $C_y$ , in year  $y$  to annual exploitation rate  $F_y$  (Table A2, data from Helser et al. 2002). The second component is a within-year ratio of sums, widow bycatch ( $w$ ) over targeted hake catch ( $h$ ). Coefficients of variation for this index were derived from the delta method (Seber 1982) as described in Rogers and Lenarz, 1993.

No clear trend is apparent in the JV and foreign fisheries (Figure A1a), while the domestic fishery shows a declining trend in CPUE (Figure A1b). To illustrate the influence of declining Hake biomass on this index, we plotted Index 1 for the domestic fishery next to the second component of the index, the ratio of widow catch over hake catch (Figure A1b). The hake fishery’s recent attempts (1999 to present) to reduce widow bycatch could potentially influence the index, so we plotted the annual proportion of tows with zero widow bycatch for all three fisheries (Figure A2).

Our second bycatch index ( $I_y^2$ , Index 2) is a direct estimate of catch per minute (Figure A3), as introduced in the previous assessment (Williams et al., 2000):

$$I_y^2 = \frac{\sum_{i=1}^{n_y} w_{iy}}{\sum_{i=1}^{n_y} d_{iy}}$$

Any records without information on tow duration were excluded from the analysis. This includes all records from the 1984 joint-venture fishery. As in the previous index, coefficients of variation were derived using a ratio estimator. Point estimates and coefficients of variation for indices 1 and 2 are summarized in Table A3.

Our third bycatch index ( $I_y^3$ , Index 3) was calculated using the delta-GLM method (Stefánsson, 1996). This index is comprised of two generalized linear models (GLMs). We fit both GLMs with year and latitude as categorical variables, binning latitudes into  $1^\circ$  increments. The first GLM estimates the probability of a positive set (widow catch per minute  $> 0$ ) using a binomial GLM with a logit link function:

$$p_i = \frac{\exp(\mathbf{m} + Y_i + \bar{L})}{1 + \exp(\mathbf{m} + Y_i + \bar{L})}$$

where  $p_i$  is the probability of a positive response in year  $i$ ,  $\mathbf{m}$  is the intercept term for the binomial GLM,  $Y_i$  is the year-specific effect, and  $\bar{L}$  is the mean latitude effect.

The second GLM estimates expected values for positive tows, using a simple normal linear model with a log-transformation of the response variable:

$$\log(y_{ijk}) = \mathbf{m} + Y_i + L_j + \mathbf{e}_{ijk}$$

where  $\mathbf{m}$  is now the intercept term for the regression model,  $Y_i$  is the year effect,  $L_j$  is the latitude effect, and  $\mathbf{e}_{ijk}$  is a normally distributed error term. Mean year-specific effects,  $M_i$ , for this model are the back-transformed regression coefficients for the ‘year’ factor:

$$M_i = \exp\left(\mathbf{m} + Y_i + \bar{L} + \frac{\mathbf{s}^2}{2}\right)$$

where  $Y_i$  is the  $i^{\text{th}}$  year effect,  $\bar{L}$  is the mean latitude effect, and  $\mathbf{s}^2$  is the mean squared error of the linear model. The final delta-GLM abundance index is simply the product of the back-transformed year effects from the two GLMs:

$$I_i^3 = \mathbf{p}_i M_i$$

To further investigate the influence of latitude on the index, we iteratively weighted the lognormal GLM portion of the index with estimated latitude effects from unweighted model runs. Iterative weighting had little to no effect on point estimates in each fishery. CVs associated with the weighted index were similar to the unweighted results, but slightly higher. Results of the unweighted index are reported here. The precision of each index was estimated using a jackknife routine. Year effects and associated coefficients of variation are summarized in Table A3.

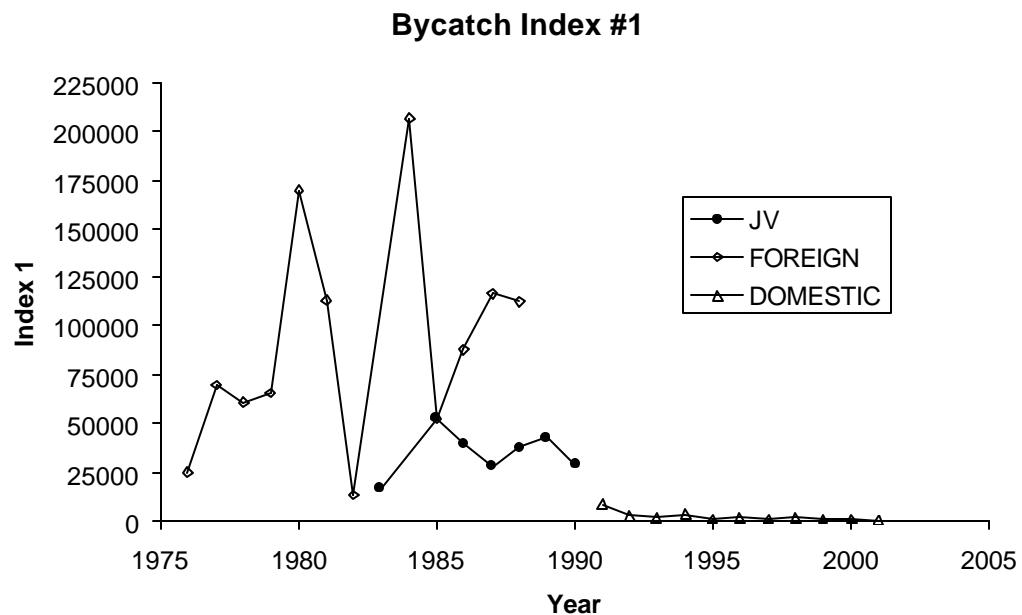
Table A2. Annual total catch of Pacific hake ( $C_y$ ) by the U.S. fishery and estimated annual exploitation rate ( $F_y$ ) from 1976 to 2001. Data are provided by Helser et al. (2002).

Year	U.S. hake catch ( $C_y$ ) (thousands t)	U.S. exploitation rate ( $F_y$ )
1976	231.549	9.2%
1977	127.502	5.9%
1978	98.372	5.1%
1979	124.680	6.7%
1980	72.352	2.8%
1981	114.760	4.7%
1982	75.577	4.1%
1983	73.150	1.6%
1984	96.332	2.0%
1985	85.439	2.0%
1986	154.964	4.3%
1987	160.448	2.7%
1988	160.698	3.3%
1989	210.996	5.1%
1990	183.800	4.6%
1991	217.505	5.6%
1992	208.576	7.0%
1993	141.222	5.2%
1994	252.729	10.9%
1995	177.589	10.4%
1996	212.902	12.8%
1997	233.423	13.5%
1998	232.817	16.0%
1999	224.522	19.7%
2000	208.418	21.7%
2001	182.377	25.6%

Table A3. Three indices and associated coefficients of variance (CV) for widow rockfish abundance based on bycatch in Pacific Hake Fisheries.

Year	Count	$\frac{C_y \cdot \sum_{i=1}^{n_y} w_{iy}}{F_y \cdot \sum_{i=1}^{n_y} h_{iy}}$	$\frac{\sum_{i=1}^{n_y} w_{iy}}{\sum_{i=1}^{n_y} d_{iy}}$	Delta-Lognormal			
		Index 1	CV	Index 2 (x1000)	CV	Index 3	CV
<b>Foreign Fishery</b>							
1976	109	24943	0.231	1.681	0.182	4.256	0.189
1977	740	69772	0.166	2.122	0.068	3.529	0.097
1978	1157	60705	0.159	2.497	0.050	3.853	0.072
1979	1149	65391	0.162	1.840	0.055	2.800	0.078
1980	511	170078	0.160	3.583	0.047	6.265	0.075
1981	770	113186	0.160	1.951	0.052	3.234	0.080
1982	189	13238	0.242	0.819	0.189	1.148	0.231
1984	587	207029	0.156	6.107	0.045	9.461	0.076
1985	1936	52290	0.159	0.933	0.051	1.397	0.082
1986	959	87890	0.159	3.176	0.048	3.893	0.075
1987	1966	116457	0.156	1.913	0.040	2.181	0.065
1988	758	112783	0.164	1.791	0.064	2.426	0.094
<b>Joint-Venture Fishery</b>							
1983	426	16415	0.158	1.150	0.052	10.591	0.111
1985	582	52391	0.162	0.994	0.060	4.706	0.140
1986	1786	39769	0.154	0.879	0.033	4.290	0.082
1987	2533	27587	0.156	0.390	0.042	1.056	0.103
1988	1947	37965	0.154	0.646	0.034	2.072	0.087
1989	2907	42459	0.152	0.900	0.022	4.644	0.059
1990	2944	28889	0.152	0.725	0.027	3.135	0.070
<b>Domestic Fishery</b>							
1991	593	8123	0.205	0.685	0.139	0.512	0.114
1992	1458	2589	0.186	0.265	0.109	0.213	0.098
1993	859	1506	0.178	0.232	0.096	0.304	0.087
1994	1603	3302	0.159	0.455	0.055	0.586	0.057
1995	814	1104	0.188	0.162	0.110	0.162	0.087
1996	1296	1450	0.164	0.241	0.065	0.336	0.069
1997	1842	1061	0.160	0.230	0.055	0.310	0.062
1998	2110	1516	0.162	0.338	0.061	0.439	0.065
1999	2629	694	0.162	0.112	0.061	0.177	0.066
2000	1942	493	0.163	0.121	0.062	0.145	0.070
2001	1759	166	0.185	0.075	0.107	0.107	0.076

**Figure A1a:**



**Figure A1b:**

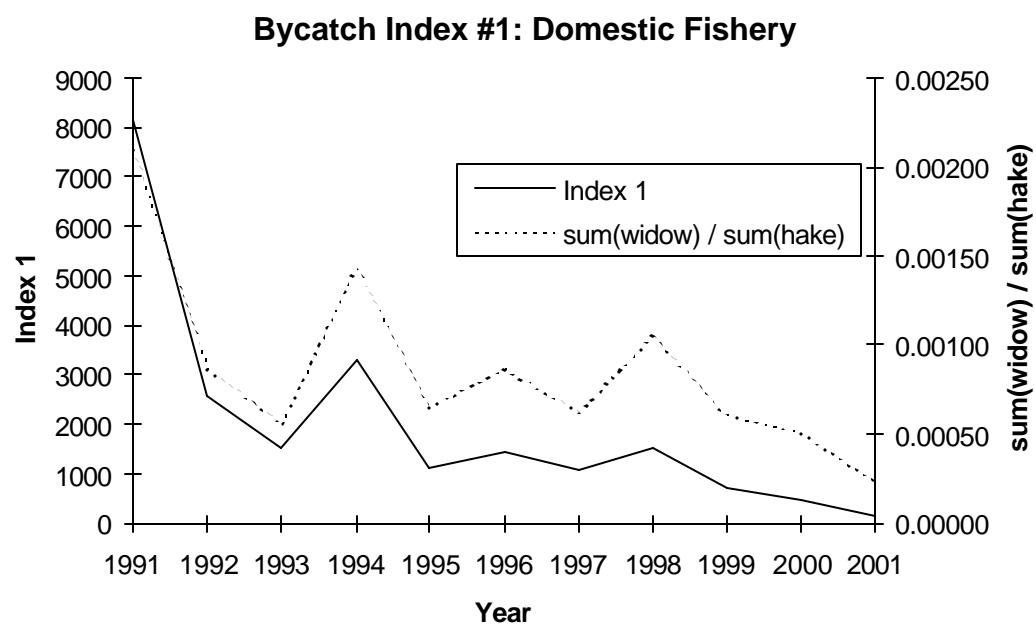


Figure A1. Time series of widow bycatch CPUE (Index 1) from three Pacific hake fisheries

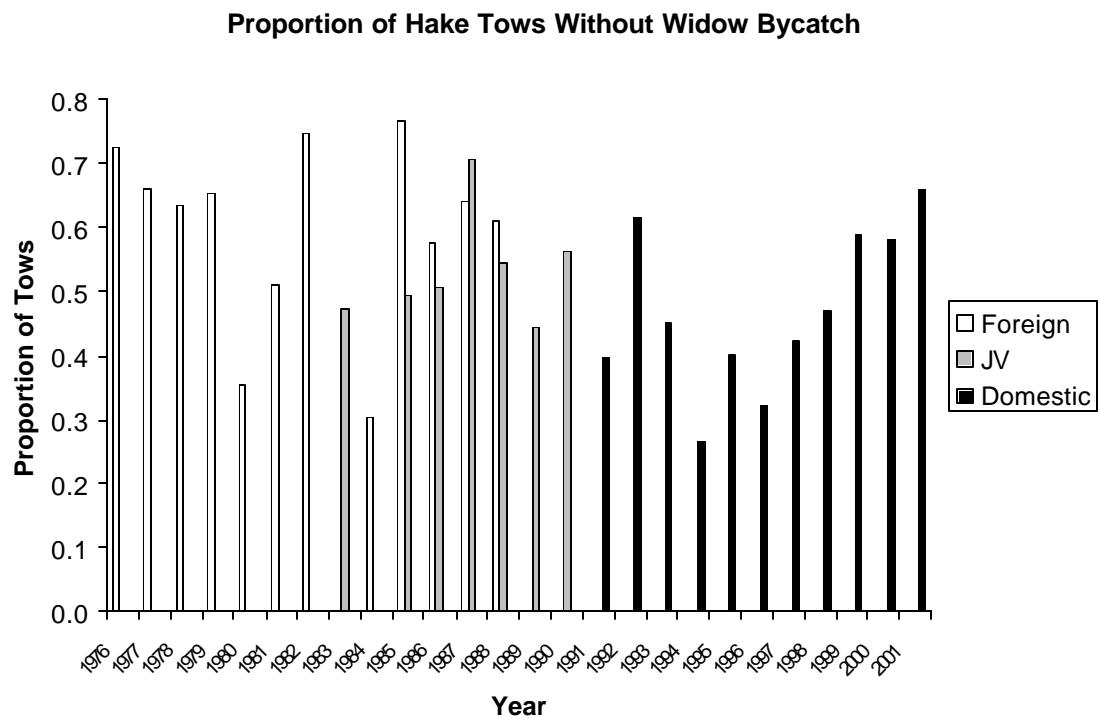


Figure A2. Proportion of tows targeting Pacific hake that resulted in zero bycatch of widow rockfish

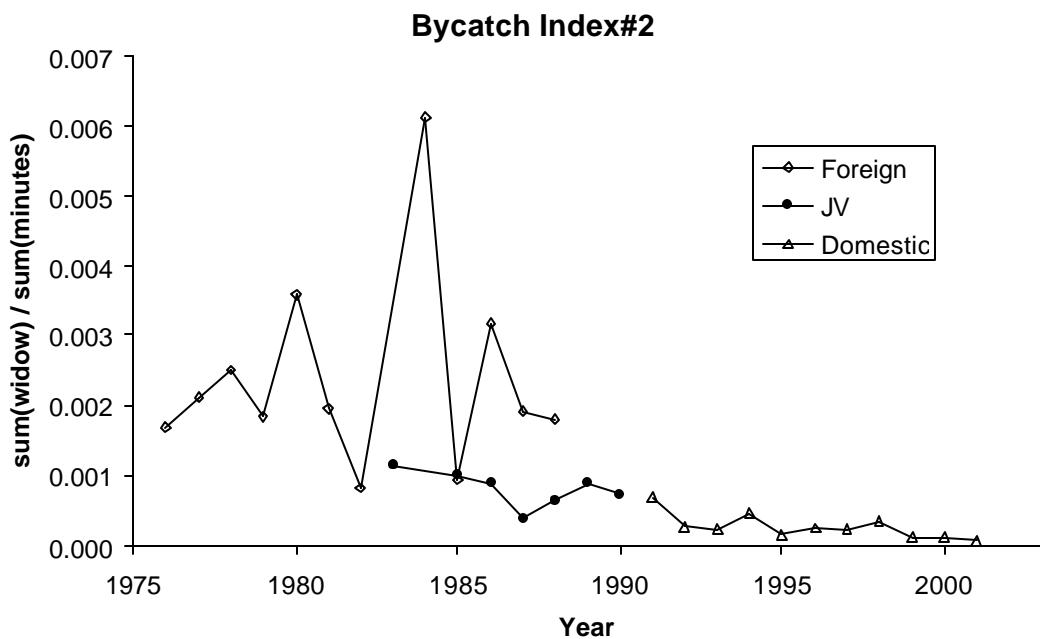


Figure A3 Time series of widow bycatch CPUE (widow/minute, Index 2) from three Pacific hake fisheries.

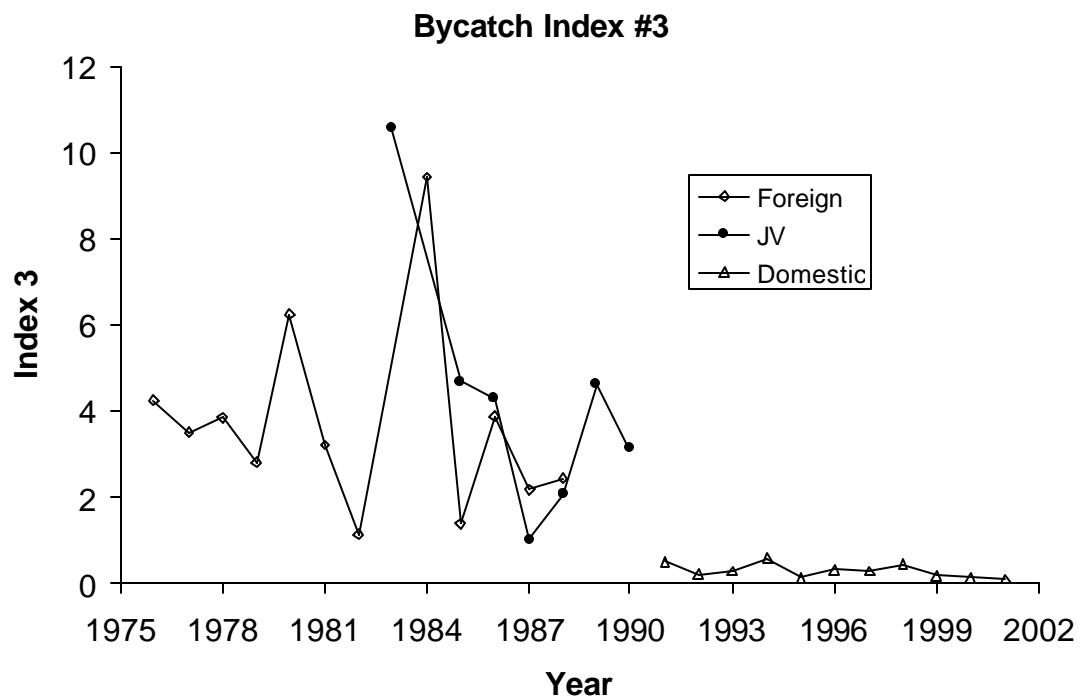


Figure A4. Time series of widow bycatch CPUE (kg widow/minute, Index 3) from three Pacific hake fisheries.

## Appendix B: Description of assessment model

The widow population is assumed to be subject to four fisheries in two regions. Region 1 consists of the Vancouver-Columbia trawl fishery, Oregon midwater trawl fishery, and Oregon bottom trawl fishery. Region 2 consists of the Eureka-Monterey-Conception trawl fishery.

### Initial condition and cohort growth:

Initial conditions of the population are numbers of fish at sex  $x$ , at age  $a$  and at the first model year ( $y = 0$ ) in 1958, which is given by:

$$N_{x,0,a} = \begin{cases} 0.5Re^{R_l^d} & \text{if } a = a_{\min} \\ N_{x,0,a-1}e^{-M_x} & \text{if } a_{\min} < a < a_{\max} \\ \frac{N_{x,0,a-1}e^{-M_x}}{1 - e^{-M_x}} & \text{if } a = a_{\max} \end{cases} \quad (9)$$

where  $R$  = mean recruitment

$R_l^d$  = recruitment residual at year 0

$a_{\min}$  = age of recruitment (minimum age in model)

$a_{\max}$  = maximum age, including age-plus groups

$M_x$  = natural mortality for sex  $x$ , which is constant across year and age

Numbers of fish in subsequent years are given by:

$$N_{x,y,a} = \begin{cases} 0.5Re^{R_y^d} & \text{if } a = a_{\min} \\ N_{x,y-1,a-1}e^{-\left(M_x + \sum_f F_{x,y-1,a-1}^f\right)} & \text{if } a_{\min} < a < a_{\max} \\ N_{x,y-1,a-1}e^{-\left(M_x + \sum_f F_{x,y-1,a-1}^f\right)} + N_{x,y-1,a_{\max}}e^{-\left(M_x + \sum_f F_{x,y-1,a_{\max}}^f\right)} & \text{if } a = a_{\max} \end{cases} \quad (10)$$

where  $R_y^d$  = recruitment residual at year  $y$ , and  $\sum_y R_y^d = 0$ .

Fishing mortality is given by:

$$F_{x,y,a}^f = FF_f e^{FF_f^d} S_{x,y,a}^f \quad (11)$$

where  $FF_f$  = full fishing mortality for fishery  $f$

$FF_{f,y}^d$  = fishing mortality residual for fishery  $f$  and at year  $y$  with  $\sum_y FF_{f,y}^d = 0$

$S_{x,y,a}^f$  = selectivity by fishery  $f$ , at sex  $x$ , year  $y$ , and age  $a$ .

### Selectivity and catch:

Double logistic selectivity was used:

$$S_a^f = \left( \frac{1}{1 + e^{-h_{2,f}(a-h_{1,f})}} \right) \left( 1 - \frac{1}{1 + e^{h_{4,f}(a-h_{3,f})}} \right) \max(s^f) \quad (12)$$

where  $\mathbf{h}_{1,f}$ ,  $\mathbf{h}_{2,f}$ ,  $\mathbf{h}_{3,f}$ , and  $\mathbf{h}_{4,f}$  = parameters to be estimated

$\max(S^f)$  = maximum selectivity by fishery  $f$ .

Double logistic selectivity allows the selectivity pattern to be dome-shaped or asymptotic on either the left or the right side of the selectivity curve. Selectivity is set to be same for both sexes, so  $S_{1,y,a}^f = S_{2,y,a}^f$ . However, selectivity may vary from year to year. In this case, year-specific parameters  $\mathbf{h}_{2,f}$ , which determine steepness of the left side of the selectivity, are estimated. If selectivity does not vary from year to year,  $S_{s,y,a}^f = S_{s,1,a}^f = S_{s,2,a}^f = \dots$ . Annual catch by fishery  $f$  at sex  $x$ , and age  $a$  is given by:

$$C_{x,y,a}^f = N_{x,y,a} \frac{F_{x,y,a}^f}{M_x + \sum_f F_{x,y,a}^f} \left( 1 - e^{-\left( M_x + \sum_f F_{x,y,a}^f \right)} \right) \quad (13)$$

Landing by fishery  $f$  at year  $y$ ,  $\Psi_y^f$ , is given by:

$$\Psi_y^f = (1 - D_y) \sum_x \sum_a C_{x,y,a}^f W_{f,x,a} \quad (14)$$

where  $W_{f,x,a}$  = weight of fish in fishery  $f$ , at sex  $x$  an age  $a$ , which is region specific (see below)

$D_y$  = annual mean discard rate.

A vector of observed proportions of catch-at-age compositions for fishery  $f$ , at sex  $x$  and year  $y$ ,  $\mathbf{T}_{x,y}^f$ , is adjusted by an ageing error matrix:

$$\mathbf{T}_{x,y}^f = \mathbf{O} \tilde{\mathbf{T}}_{x,y}^f \quad (15)$$

where  $\tilde{\mathbf{T}}_{x,y}^f$  = vector of proportions of catch-at-age compositions from catch-age expansion data

$\mathbf{O}$  = ageing error matrix with dimension of  $A * A$  ( $A$  is number of age class), and each column representing probabilities of true age.

### Biomass and spawning output:

Annual biomass at sex  $x$  and age  $a$  is given by:

$$B_{x,y,a} = \sum_r \mathbf{f}_r N_{x,y,a} W_{r,x,a} \quad (16)$$

where  $\mathbf{f}_r$  = proportion of population in region  $r$ , and  $\sum_r \mathbf{f}_r = 1$

$W_{r,x,a}$  = weight of fish in region  $r$  at sex  $x$  and age  $a$ .

Annual spawning biomass is given by:

$$SSB_y = \sum_r \mathbf{f}_r P_{r,a} N_{2,y,a} W_{r,2,a} \quad (17)$$

where  $P_{r,a}$  = proportion of mature females ( $x=2$ ) in region  $r$  and at age  $a$ .

Annual spawning output is given by:

$$SO_y = \sum_r f_r P_{r,a} N_{2,y,a} G_{r,a} \quad (18)$$

where  $G_{r,a}$  = fecundity in region  $r$  and at age  $a$ , and is derived from an empirical relationship (Boehlert et al. 1982):

$$G_{r,a} = 605.71W_{r,2,a} - 261830.7 \quad (19)$$

Note that the spawning output of year 0 ( $SO_0$ ), which is also termed as  $B_0$ , is an important parameter often used for determining target population levels.

### Growth, length-weight relationship:

$$L_{r,x,a} = L_{r,x}^\infty \left( 1 - e^{-K_{r,x}(a-t_{r,x}^0)} \right) \quad (20)$$

$$W_{r,x,a} = t_r^1 L_a^{t_r^2} \quad (21)$$

where  $L_{r,x,a}$  = length in region  $r$  at sex  $x$  and age  $a$

$L_{r,x}^\infty$ ,  $K_{r,x}$ , and  $t_{r,x}^0$  = growth parameters in region  $r$  and at sex  $x$

$t_r^1$  and  $t_r^2$  = length-weight parameters in region  $r$ .

### Stock-recruit relationship:

The Beverton-Holt relationship is used:

$$R_y = \frac{SO_{y-a_{\min}}}{\mathbf{a} + \mathbf{b} SO_{y-a_{\min}}} e^{R_y^d} \quad (22)$$

where  $R_y$  = recruitment in billions of eggs at year  $y$

$SO_{y-a_{\min}}$  = spawning output at year  $y - a_{\min}$

$\mathbf{a}$  and  $\mathbf{b}$  = recruitment parameters to be estimated.

The relationship can be reparameterized by using a steepness parameter ( $h$ ):

$$\mathbf{a} = \frac{\frac{B_0}{R}(1-h)}{4h} \quad (23)$$

and

$$\mathbf{b} = \frac{5h-1}{4hR} \quad (24)$$

where  $B_0$  and  $R_0$  are defined previously ( $B_0 = SO_0$ ).

The “steepness” is the expected fraction of  $R_0$  at  $0.2B_0$ , and is set to range from 0.2 to 1.0. When  $h=0.2$ , recruits are a linear function of spawning output ( $\mathbf{b}=0$ , and

$R_y = \frac{1}{\mathbf{a}} SO_{y-a_{\min}} e^{R_y^d}$ ). When  $h=1$ , recruits are constant and independent of spawning output ( $\mathbf{a}=0$ , and  $R_y = \frac{1}{\mathbf{b}} e^{R_y^d}$ ).

### **Likelihood components:**

Total likelihood is the sum of all individual likelihood from catch-at-age compositions, fishery landings, and CPUE indexes from surveys and commercial catch data. Where there are missing observed values, the likelihood values are set to zeros. The total negative logarithm of the likelihood, which will be minimized during the parameter estimation, is given by:

$$-\log(L) = \sum_i I_i L_i \quad (25)$$

where  $L_i$  = likelihood value for component  $i$

$I_i$  = weighting factor for component  $i$ .

### Catch-at-age composition:

$$L_1 = -\sum_f \sum_y n_y^f \sum_x \sum_a q_{x,y,a}^f \log \left( \frac{\hat{q}_{x,y,a}^f}{q_{x,y,a}^f} \right) \quad (26)$$

where  $\mathbf{q}$  and  $\hat{\mathbf{q}}$  = observed and estimated proportions of catch-at-age compositions by fishery  $f$  at sex  $x$ , year  $y$ , and age  $a$

$n_y^f$  = sampled trips in fishery  $f$  and year  $y$ .

### Landings:

$$L_2 = \sum_f \left\{ \frac{\left[ \log(\Psi_y^f) - \log(\hat{\Psi}_y^f) \right]^2}{2(\mathbf{s}_f^\Psi)^2} + \log(\mathbf{s}_f^\Psi) \right\} \quad (27)$$

where  $\Psi_y^f$  and  $\hat{\Psi}_y^f$  = observed and estimated landings by fishery  $f$  in year  $y$

$\mathbf{s}_f^\Psi$  = standard error for  $\log(\Psi_y^f)$  which is set to be small (0.05) based on the assumption of small observation errors of catch data.

### Recruitment:

Recruitment residuals are assumed to have no autocorrelations:

$$L_3 = 0.5 \sum_y \left[ \left( \frac{R_y^d}{\mathbf{s}_R} \right)^2 - \log(\mathbf{s}_R) \right] \quad (28)$$

### Survey and CPUE indexes:

$$L_{4-8} = \sum_j \left\{ \frac{\left[ \log(I_{j,y}) - \log(\hat{I}_{j,y}) \right]^2}{2(\mathbf{s}_j^I)^2} + \log(\mathbf{s}_j^I) \right\} \quad (29)$$

where  $I_{j,y}$  and  $\hat{I}_{j,y}$  = observed and estimated index from series  $j$  and year  $y$

$\mathbf{s}_j^I$  = standard error for  $\log(I_{j,y})$ .

## Appendix C. AD Model Builder code for the widow rockfish assessment model.

```
// ****
// Widow Rockfish Model
//
// Erik H. Williams, NMFS, Santa Cruz/Tiburon Lab
// (erik.williams@noaa.gov), May 2000
// Modified by Xi He 2003
// NMFS Santa Cruz Lab, xi.he@noaa.gov
// *****

GLOBALS_SECTION
#include <time.h>
time_t start,finish;
long hour,minute,second;
double elapsed_time;
char s1[2] = {" "};

TOP_OF_MAIN_SECTION
arrmblsize=1000000;
gradient_structure::set_MAX_NVAR_OFFSET(1600);
gradient_structure::set_GRADSTACK_BUFFER_SIZE(1000000);
gradient_structure::set_CMPDIF_BUFFER_SIZE(1000000);
time(&start);
cout << endl << "Start time: " << ctime(&start) << endl;

DATA_SECTION
init_int nr;
init_int nf;
init_int ns; //number of sex: male s=1 & female s=2
init_int ni;
init_int syr;
init_int eyr;
init_int ny;
init_int recage;
init_int na;
init_ivector agebins(1,na);
init_int nL;
init_vector M(1,ns);
init_vector D(1,ny);
```

```

init_vector fracLN(1,ny);
init_matrix Linf(1,nr,1,ns);
init_matrix K(1,nr,1,ns);
init_matrix t0(1,nr,1,ns);
init_vector Lena(1,ns);
init_vector Lenb(1,ns);
init_matrix mat(1,nr,1,na);
init_matrix fec(1,nr,1,na);
init_matrix obsI(1,ni,1,ny);
init_matrix obsIcv(1,ni,1,ny);
init_matrix obsL(1,nf,1,ny);

init_int nyr_agec1;
init_ivector yr_agec1(1,nyr_agec1);
init_vector nsamp_agec1(1,nyr_agec1);
init_matrix obs_agec1_f(1,nyr_agec1,1,na);
init_matrix obs_agec1_m(1,nyr_agec1,1,na);
init_int nyr_agec2;
init_ivector yr_agec2(1,nyr_agec2);
init_vector nsamp_agec2(1,nyr_agec2);
init_matrix obs_agec2_f(1,nyr_agec2,1,na);
init_matrix obs_agec2_m(1,nyr_agec2,1,na);
init_int nyr_agec3;
init_ivector yr_agec3(1,nyr_agec3);
init_vector nsamp_agec3(1,nyr_agec3);
init_matrix obs_agec3_f(1,nyr_agec3,1,na);
init_matrix obs_agec3_m(1,nyr_agec3,1,na);
init_int nyr_agec4;
init_ivector yr_agec4(1,nyr_agec4);
init_vector nsamp_agec4(1,nyr_agec4);
init_matrix obs_agec4_f(1,nyr_agec4,1,na);
init_matrix obs_agec4_m(1,nyr_agec4,1,na);
init_matrix age_error(1,na,1,na);
init_int eyr_B0;
init_int syr_rec;
init_int nyr_weight;
init_int RecruitOverRiding;

int r;
int f;
int y;

```

```

int a;
int s;
int n_output;
ivector FYWC(1,nf);

PARAMETER_SECTION
init_number logInitScale(3);
init_bounded_number h(0.2,1.0,3);
init_bounded_dev_vector rec_dev(1,ny,-2.5,2.5,1);
init_bounded_matrix Sp(1,nf,1,4,0.0,30.0,4);
init_bounded_vector log_q(1,ni,-80.0,0.0,4);
init_vector Favg(1,nf,2);
init_bounded_dev_vector F1_dev(1966,2002,-5.0,3.0,2);
init_bounded_dev_vector F2_dev(1983,2002,-3.0,2.0,2);
init_bounded_dev_vector F3_dev(1983,2002,-5.0,3.0,2);
init_bounded_dev_vector F4_dev(1966,2002,-8.0,4.0,2);

matrix Ninit(1,ns,1,na);
number B0;
number B0RecMean;
number BT;
number R0;
number alpha;
number beta;
number SPR;
3darray N(1,ns,1,ny,1,na);
3darray B(1,ns,1,ny,1,na);
vector recE(1,ny);
vector recP(1,ny);
sdreport_vector totB(1,ny);
sdreport_vector SSB(1,ny);
sdreport_vector SO(1,ny);
likeprof_number BToverB0;

4darray C(1,nf,1,ns,1,ny,1,na);
3darray CT(1,ns,1,ny,1,na);
4darray L(1,nf,1,ns,1,ny,1,na);

4darray F(1,nf,1,ns,1,ny,1,na);
matrix Fdev(1,nf,1,ny);
3darray FT(1,ns,1,ny,1,na);

```

```

3darray Z(1,ns,1,ny,1,na);

vector sigL(1,nf);

4darray obsA(1,nf,1,ns,1,ny,1,na);
4darray predA(1,nf,1,ns,1,ny,1,na);
matrix nsampA(1,nf,1,ny);
matrix predL(1,nf,1,ny);
3darray S(1,nf,1,ny,1,na);

vector SCL_I(1,ny);
matrix predI(1,ni,1,ny);
3darray Len(1,nr,1,ns,1,na);
3darray W(1,nr,1,ns,1,na);

number pow_mwt;
vector Icv(1,ni);
number sigR;
vector sigI(1,ni);
vector obsIn(1,ni);

matrix LKLA(1,nf,1,ny)
vector lambda(1,nL);
vector LKL(1,nL);
objective_function_value fv;

INITIALIZATION_SECTION

RUNTIME_SECTION
maximum_function_evaluations 1000 2000 3000 4000 5000 6000;
convergence_criteria 1e-8 1e-8 1e-8 1e-8 1e-9 1e-9;

PRELIMINARY_CALCS_SECTION
int r,s,a,aa,i;
//compute length and weight at age
for(r=1;r<=nr;r++)
for(s=1;s<=ns;s++)
for(a=1;a<=na;a++)
{
    aa = a+recage-1;
    if (a==na) aa += 2; //age 22 used for max age (age of 20)
}

```

```

Len(r,s,a) = Linf(r,s)*(1.0-mfexp(-K(r,s)*(aa-t0(r,s)))); 
W(r,s,a) = 0.001*Lena(s)*pow(Len(r,s,a),Lenb(s));           //W now is kg
}

//Weights for likelihood components
lambda(1)=1.0;      //Age comps
lambda(2)=1.0;      //Landing
lambda(3)=0.5;      //Recruitment deviations
lambda(4)=0.5;      //CPUE index SCL juvenile survey
lambda(5)=1.0;      //CPUE index OR bottom trawl logbook
lambda(6)=1.0;      //CPUE index whiting foreign
lambda(7)=1.0;      //CPUE index whiting joint venture
lambda(8)=1.0;      //CPUE index whiting domestic

//for (y=(ny-3);y<=ny;y++) D(y) = 0.01; // for changes in discard rates

//sigmas
sigL = 0.05;
sigR = 0.5;
pow_mwt = 3.0;
Icv(1) = 0.964256;
Icv(2) = 0.408837;
Icv(3) = 0.573773;
Icv(4) = 0.792426;
Icv(5) = 0.427578;

//Icv = 0.5;

SCL_I = obsI(1);
for(y=(ny-recage+1);y<=ny;y++) obsI(1,y) = (-1.0);
predI = obsI;
predL = obsL;

// assign age comp data to 4d matrix, if no data, value = -1
// Note: no operator defined for (4darray = 0) in ADMB
for(f=1;f<=nf;f++) for(s=1;s<=ns;s++) for(y=1;y<=ny;y++) for(a=1;a<=na;a++)
  obsA(f,s,y,a) = predA(f,s,y,a) = (-1.0);

int yy;
for(a=1;a<=na;a++)
{

```

```

for(y=1;y<=nyr_agec1;y++)
{
    yy = yr_agec1(y)-syr+1;
    obsA(1,1,yy,a) = obs_agec1_f(y,a);
    obsA(1,2,yy,a) = obs_agec1_m(y,a);
}

for(y=1;y<=nyr_agec2;y++)
{
    yy = yr_agec2(y)-syr+1;
    obsA(2,1,yy,a) = obs_agec2_f(y,a);
    obsA(2,2,yy,a) = obs_agec2_m(y,a);
}

for(y=1;y<=nyr_agec3;y++)
{
    yy = yr_agec3(y)-syr+1;
    obsA(3,1,yy,a) = obs_agec3_f(y,a);
    obsA(3,2,yy,a) = obs_agec3_m(y,a);
}

for(y=1;y<=nyr_agec4;y++)
{
    yy = yr_agec4(y)-syr+1;
    obsA(4,1,yy,a) = obs_agec4_f(y,a);
    obsA(4,2,yy,a) = obs_agec4_m(y,a);
}
}

cout << "obsA(1,2,20,6) = " << obsA(1,2,20,6) << endl; // should print 0.056797
cout << "obsA(4,2,34,10) = " << obsA(4,2,34,10) << endl; // should print 0.032407

nsampA = (-1.0);
for(y=1;y<=nyr_agec1;y++)
    nsampA(1,yr_agec1(y)-syr+1) = nsamp_agec1(y);
for(y=1;y<=nyr_agec2;y++)
    nsampA(2,yr_agec2(y)-syr+1) = nsamp_agec2(y);
for(y=1;y<=nyr_agec3;y++)
    nsampA(3,yr_agec3(y)-syr+1) = nsamp_agec3(y);
for(y=1;y<=nyr_agec4;y++)
    nsampA(4,yr_agec4(y)-syr+1) = nsamp_agec4(y);

```

```

for(f=1;f<=nf;f++)
for(y=1;y<=ny;y++)
  if (obsL(f,y)>(-1.0))
  {
    FYWC(f) = y;           //FYWC = first year with catch
    break;
  }

// compute num of years with observations for each CPUE index
// Note: last three years (recage) SC Lab survey are not used
for (i=1;i<=ni;i++)
{
  if (i==1) yy = ny-recage;
  else yy = ny;
  for (y=1;y<=yy;y++)
  if ( obsI(i,y) > (-1.0) )
    obsIn(i) += 1.0;
}
cout << "obsIn = " << obsIn << endl;

n_output = 0;

PROCEDURE_SECTION
  get_initial_age_structure();
  get_selectivity();
  get_mortality();
  get_numbers_at_age();
  get_catch_at_age();
  get_predI();
  get_pred_agecomps();
  evaluate_the_objective_function();

  if(mceval_phase())
  {
    n_output++;
    write_mceval_output_files(n_output);
  }

FUNCTION get_initial_age_structure
  int s,a;

```

```

R0 = mfexp(logInitScale);
Ninit(1,1) = Ninit(2,1) = 0.5*R0;           // assuming sex ratio = 1:1
for(s=1;s<=ns;s++)
{
    for(a=2;a<=na;a++) Ninit(s,a) = Ninit(s,a-1)*mfexp(-M(s));
    Ninit(s,na) = Ninit(s,na-1)*mfexp(-M(s))/(1.0-mfexp(-M(s))); // additional term for age+ group
}

// Ninit(2), fracLN(1), mat(1), and fec(1) are vectors of size na
B0 = sum(elem_prod( elem_prod((Ninit(2)*fracLN(1)),mat(1)),fec(1))
        + elem_prod( elem_prod((Ninit(2)*(1-frcLN(2))),mat(2)),fec(2)));
alpha = (B0/R0)*(1.0-h)/(4.0*h);
beta = (5.0*h-1.0)/(4.0*h*R0);

FUNCTION get_selectivity
for(f=1;f<=nf;f++) for(y=1;y<=ny;y++) for(a=1;a<=na;a++)
    S(f,y,a) = DLogSel(Sp(f,1),double(agebins(a)),Sp(f,2),Sp(f,3),double(agebins(a)),Sp(f,4));
for(f=1;f<=nf;f++) for(y=1;y<=ny;y++) S(f,y) /= max(S(f,y));

FUNCTION get_mortality
for(f=1;f<=nf;f++)
for(s=1;s<=ns;s++)
for(y=1;y<=ny;y++)
{
    if( y >= FYWC(f) )
    {
        if (f==1) Fdev(f,y) = F1_dev(y+syr-1);
        if (f==2) Fdev(f,y) = F2_dev(y+syr-1);
        if (f==3) Fdev(f,y) = F3_dev(y+syr-1);
        if (f==4) Fdev(f,y) = F4_dev(y+syr-1);
        F(f,s,y)=S(f,y)*mfexp(Favg(f)+Fdev(f,y));
    }
}

for(s=1;s<=ns;s++)
{
    FT(s) = 0.0;
    for(f=1;f<=nf;f++)
        FT(s) += F(f,s);
    Z(s) = FT(s) + M(s);
}

```

```

FUNCTION get_numbers_at_age
dvariable SO1;

for(s=1;s<=ns;s++)
for(a=1;a<=na;a++)
  N(s,1,a) = Ninit(s,a);

for(y=1;y<=ny;y++)
{
  if( y<=recage ) SO1 = B0;
  else SO1 = SO(y-recage);
  recP(y) = Recruit(SO1,alpha,beta,1);
  recE(y) = recP(y)*mfexp(rec_dev(y));

  for(s=1;s<=ns;s++)
  {
    N(s,y,1) = 0.5*recE(y);
    if( y<ny )
    {
      for(a=1;a<na;a++)
        N(s,y+1,a+1) = N(s,y,a)*mfexp(-Z(s,y,a));
      N(s,y+1,na) += N(s,y,na)*mfexp(-Z(s,y,na));
    }
    for(a=1;a<na;a++)
      B(s,y,a) = N(s,y,a)*W(1,s,a)*fracLN(y) + N(s,y,a)*W(2,s,a)*(1.0-frcLN(y));
  }
  totB(y) = sum(B(1,y)+B(2,y));
  SSB(y) = SO(y) = 0.0;
  for(a=1;a<=na;a++)
  {
    SSB(y) += N(2,y,a)*W(1,2,a)*mat(1,a)*fracLN(y) + N(2,y,a)*W(2,2,a)*mat(2,a)*(1.0-frcLN(y));
    SO(y) += N(2,y,a)*fec(1,a)*mat(1,a)*fracLN(y) + N(2,y,a)*fec(2,a)*mat(2,a)*(1.0-frcLN(y));
  }
}

int NyrRecMean = eyr_B0 - syr - recage + 1;
dvector recValue(1,NyrRecMean);
for (y=1;y<=NyrRecMean;y++) recValue(y) = value(recE(y+recage));

```

```

dvariable recMean,SPRnorth,SPRsouth;
recMean = mean(recValue);
SPRnorth = CalsPR(na, mat(1), fec(1), M(2));
SPRsouth = CalsPR(na, mat(2), fec(2), M(2));
SPR = fracLN(1)*SPRnorth + (1.0-frcLN(1))*SPRsouth;
B0RecMean = SPR*recMean;
//cout << "SPRnorth = " << SPRnorth << " SPRsouth = " << SPRsouth << " SPR = " << SPR << endl;
//cout << "recMean = " << recMean << " B0RecMean = " << B0RecMean << endl;

BT = SO(ny);
BToverB0 = BT/B0;

FUNCTION get_catch_at_age
for(s=1;s<=ns;s++)
for(y=1;y<=ny;y++)
for(a=1;a<=na;a++)
{
  for(f=1;f<=nf;f++)
    C(f,s,y,a) = N(s,y,a)*F(f,s,y,a)*(1.0-mfexp(-Z(s,y,a)))/Z(s,y,a);

    CT(s,y,a)=N(s,y,a)*FT(s,y,a)*(1.-mfexp(-Z(s,y,a)))/Z(s,y,a);
}
for(f=1;f<=nf;f++)
{
  if(f<=3) r=1;
  if(f==4) r=2;
  for(s=1;s<=ns;s++) for(y=1;y<=ny;y++) for(a=1;a<=na;a++)
    L(f,s,y,a) = C(f,s,y,a)*W(r,s,a)*(1.0-D(y));
}

//predicted landings
for(y=1;y<=ny;y++) for(f=1;f<=nf;f++)
  predL(f,y) = sum(L(f,1,y)+L(f,2,y));

FUNCTION get_predI
  int yy,fi,i;
  dvariable x;

  // predict mid-water juvenile survy index (i=1), offset by recage years

```

```

for (y=1;y<=(ny-recage);y++)
if ( obsI(1,y)>(-1.0) )
{
    YY = y+recage;
    x = (N(1,YY,1)*mfexp(M(1)*3.0) + N(2,YY,1)*mfexp(M(2)*3.0));
    predI(1,y) = mfexp(log_q(1))*pow(x,pow_mwt);
}

// predict Oregon bottom trawl index (i=2), and whiting fishery indexes (i=3,4,5)
for (i=2;i<=5;i++)
for (y=1;y<=ny;y++)
if ( obsI(i,y)>(-1.0) )
{
    if (i==2) fi=3;                                //fi=3 for Oregon bottom trawl: fishery = 3
    if ( (i>=3) && (i<=5) ) fi=2;                //fi=2 for Oregon mid-water trawl: fishery = 2
    x = B(1,y)*S(fi,y) + B(2,y)*S(fi,y);
    predI(i,y) = mfexp(log_q(i))*x;
}

FUNCTION get_pred_agecomps
for(f=1;f<=nf;f++)
for(s=1;s<=ns;s++)
for(y=1;y<=ny;y++)
if ( (nsampA(f,y))>(-1.0) )
{
    for (a=1;a<=na;a++)           // predA = props of each is over all ages and both sexes
        predA(f,s,y,a) = C(f,s,y,a)/(sum(C(f,1,y))+sum(C(f,2,y)));
    predA(f,s,y) = age_error*predA(f,s,y);
}

FUNCTION evaluate_the_objective_function
dvariable x1,x2,x3;
double tiny = 1.0e-6;

LKLA = 0.0;
LKL = 0.0;

// LKL(1) = age compositions -> multinomial errors
for(f=1;f<=nf;f++)
for(y=1;y<=ny;y++)
{

```

```

if (nsampA(f,y)>(-1.0))
{
  for(s=1;s<=ns;s++)
    for(a=1;a<=na;a++)
    {
      x1 = obsA(f,s,y,a)+tiny;
      x2 = predA(f,s,y,a)+tiny;
      LKLA(f,y) += x1*log(x2/x1);
    }
  LKLA(f,y) *= nsampA(f,y);
}
LK(1) = (-1.0)*sum(LKLA);

// LKL(2) = landings -> lognormal
for(f=1;f<=nf;f++)
for(y=1;y<=ny;y++)
  if (obsL(f,y)>(-1.0))
  {
    x1 = log(obsL(f,y)+tiny);
    x2 = log(predL(f,y)+tiny);
    x3 = sigL(f);
    LKL(2) += 0.5 * square( (x1-x2)/x3 ) + log(x3);
  }

// LKL(3) = recruitment residuals -> lognormal
for(y=1;y<=ny;y++)
  LKL(3) += 0.5 * square(rec_dev(y)/sigR) + log(sigR);

// This addtional component from Methot (2000) Stock Synthesis
// It is related to good fits for obs mean and variability of individual year recruitment
// This component has very little effect
dvariable A7,T1,sigR1 = 0.0;
A7 = double(ny);
T1 = sum(rec_dev);
for(y=1;y<=ny;y++) sigR1 += square(rec_dev(y));
sigR1 = sqrt(sigR1/A7);

LKL(3) += 0.5*square(A7*(sigR1-sigR)/square(sigR)) + log(square(sigR)/A7)
+0.5*square(A7*T1/sigR) + log(sigR/A7);

```

```

// LKL(4-8) = CPUE indices -> lognormal
// computer root mean square error (RMSE) as sigmas for indices in whiting bycatch
// data CVs are used for SC Lab survey and OR bottom trawl indices
int i;
sigI = 0.0;
for (i=1;i<=ni;i++)
{
for (y=1;y<=ny;y++)
if ( obsI(i,y) > (-1.0) )
{
x1 = log(obsI (i,y)+tiny);
x2 = log(predI(i,y)+tiny);
sigI(i) += square(x1-x2);
}
sigI(i) = sqrt(sigI(i)/obsIn(i));
}
//cout << "sigI = " << sigI << endl;
//cout << "Icv = " << Icv << endl;

for (i=1;i<=ni;i++)
for (y=1;y<=ny;y++)
if ( obsI(i,y) > (-1.0) )
{
x1 = log(obsI (i,y)+tiny);
x2 = log(predI(i,y)+tiny);
x3 = Icv(i);
//if (i<=2) x3 = obsIcv(i,y);
//if (i>2) x3 = sigI(i);
// obs CVs of whiting bycatch indices from delta-GLM seems too small
// so computed sigmas are used for whiting indices
LKL(i+3) += 0.5 * square( (x1-x2)/x3 ) + log(x3);
}

fv = sum(elem_prod(LKL,lambda));

//fv += 0.5*square(log(0.52/h)/0.5);

FUNCTION dvariable CalSPR(int na, dvector mat, dvector fec, dvariable M)
dvariable Rec,SPR=0.0;
for(a=1;a<=na;a++)
{

```

```

    if (a==1) Rec = 1.0;
    else if (a==na) Rec *= mfexp(-M)/(1.0-mfexp(-M));
    else Rec *= mfexp(-M);
    SPR += Rec*mat(a)*fec(a);
}
return 0.5*SPR;

FUNCTION dvariable DLogSel(dvariable s1, dvariable L1, dvariable L501, dvariable s2, dvariable L2,
dvariable L502)
    return LogSel(s1,L1,L501)*(1.-LogSel(s2,L2,L502));

FUNCTION dvariable LogSel(dvariable s, dvariable L, dvariable L50)
    return 1./(1.+mfexp(-1.*s*(L-L50)));

FUNCTION dvariable Recruit(dvariable s, dvariable a, dvariable b, int RecruitType)
    dvariable r;
    switch(RecruitType)
    {
        case 0: r = a*s; break;
        case 1: r = s/(a+b*s); break; //Beverton and Holt
        case 2: r = s*mfexp(a*(1.0-s/b)); break; //Ricker
        case 3: r = b+a*s; break;
        default: r = 0.0; break;
    }
    if (r<0.0) r = 0.0;
    return r;

REPORT_SECTION
report << SO << endl;
report << SSB << endl;

FINAL_SECTION
write_output_files();
write_rebuild_file();
bool runmcmc1 = false, runsir1 = false;
adstring ar,ar1="-mcmc1",ar2="-sir1";
for(int i=0;i<argc;i++)
{
    ar = argv[i];
    if (ar == ar1) runmcmc1 = true;
    if (ar == ar2) runsir1 = true;
}

```

```
}

if (runmcmc1) mcmc1();
if (runsir1) sir1();
time(&finish);
elapsed_time = difftime( finish, start );
hour = long(elapsed_time)/3600;
minute = long(elapsed_time)%3600/60;
second = (long(elapsed_time)%3600)%60;
cout << ctime(&start);
cout << ctime(&finish);
cout << hour << s1 << minute << s1 << second << endl;
```

## **Appendix D. AD Model Builder data file for the widow rockfish assessment model.**

```

0.16 0.16 0.16 0.16 0.16
0.16 0.16 0.16 0.16 0.16
0.16 0.16 0.16 0.16 0.16
0.16 0.16 0.16 0.16 0.16

# Smoothed fraction of total landings in the north\
# fractions from 1968-77 was used in years before 1968, same as in 2000 assessment
# foreign landings from Jean Rogers were not used to compute fractions before 1968
0.548 0.548 0.548 0.548 0.548
0.548 0.548 0.548 0.548 0.548
0.548 0.548 0.548 0.548 0.548
0.548 0.548 0.548 0.548 0.569
0.598 0.594 0.593 0.600 0.609
0.669 0.675 0.673 0.709 0.732
0.751 0.775 0.793 0.796 0.784
0.776 0.777 0.762 0.765 0.746
0.735 0.750 0.750 0.750 0.750

# Biological information
# Growth parameters (Linf,K,t0 for male north, female north, male south, female south)
# age 22 used for wgt of 20+
44.00 50.54 41.50 47.55
0.18 0.14 0.25 0.20
-2.81 -2.68 -0.28 -0.17

# Length weight parameters (b and a for male and female)
0.01188      0.00545
3.06631      3.28781

# proportions of maturity of females
# north
0.01 0.02 0.10 0.32 0.68 0.90 0.98 0.99 1.00
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
# south
0.13 0.21 0.64 0.90 0.90 1.00 1.00 1.00 1.00
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00

# fecundity of females (millions of eggs)
# north
0.0000      0.0000      0.0723      0.1526      0.2325      0.3102      0.3843      0.4540      0.5186
0.5780      0.6322      0.6812      0.7253      0.7648      0.8000      0.8313      0.8590      0.9241

```

```

# south
0.0050    0.0100    0.0300    0.0861    0.1788    0.2664    0.3466    0.4184    0.4813
0.5358    0.5824    0.6219    0.6552    0.6831    0.7064    0.7258    0.7419    0.7751

# index values 1968-1999 (-1 = no data)
# NMFS Tiburon/Santa Cruz Lab midwater trawl index
# note that there were no estimates in 1992, 1996, and 1998 because of no positive catches
# 1/2 of historical low estimates (value in 1994) were used in those years.
# CVs were set very high.
-1.000000  -1.000000  -1.000000  -1.000000  -1.000000
-1.000000  -1.000000  -1.000000  -1.000000  -1.000000
-1.000000  -1.000000  -1.000000  -1.000000  -1.000000
-1.000000  -1.000000  -1.000000  -1.000000  -1.000000
-1.000000  -1.000000  -1.000000  -1.000000  -1.000000
-1.000000  5.632788  14.888214  0.217432  4.905919
3.429141  0.141987  0.177756  1.178180  0.061000
0.821537  0.122072  0.164556  0.061000  0.176620
0.061000  0.191478  0.219956  0.889779  6.779168

# Oregon bottom trawl index
-1.000000  -1.000000  -1.000000  -1.000000  -1.000000
-1.000000  -1.000000  -1.000000  -1.000000  -1.000000
-1.000000  -1.000000  -1.000000  -1.000000  -1.000000
-1.000000  -1.000000  -1.000000  -1.000000  -1.000000
-1.000000  -1.000000  -1.000000  -1.000000  -1.000000
-1.000000  331.47      100.88      227.08      169.08
93.97     164.10      78.49       73.59      83.16
53.58     100.34      109.96      94.81       97.23
56.56     84.46      -1.000000  -1.000000  -1.000000

# Whiting bycatch index - foreign
-1.000000  -1.000000  -1.000000  -1.000000  -1.000000
-1.000000  -1.000000  -1.000000  -1.000000  -1.000000
-1.000000  -1.000000  -1.000000  -1.000000  -1.000000
-1.000000  -1.000000  -1.000000  4.256054   3.529378
3.853356  2.800117  6.265249  3.234098  1.147622
-1.000000  9.460566  1.397218  3.893429  2.181040
2.426066  -1.000000  -1.000000  -1.000000  -1.000000
-1.000000  -1.000000  -1.000000  -1.000000  -1.000000
-1.000000  -1.000000  -1.000000  -1.000000  -1.000000

```

```

# Whiting bycatch index - joint venture (JV)
-1.000000 -1.000000 -1.000000 -1.000000 -1.000000
-1.000000 -1.000000 -1.000000 -1.000000 -1.000000
-1.000000 -1.000000 -1.000000 -1.000000 -1.000000
-1.000000 -1.000000 -1.000000 -1.000000 -1.000000
-1.000000 -1.000000 -1.000000 -1.000000 -1.000000
10.590847 -1.000000 4.706416 4.289842 1.055527
2.072460 4.643640 3.134886 -1.000000 -1.000000
-1.000000 -1.000000 -1.000000 -1.000000 -1.000000
-1.000000 -1.000000 -1.000000 -1.000000 -1.000000

# Whiting bycatch index - domestic
-1.000000 -1.000000 -1.000000 -1.000000 -1.000000
-1.000000 -1.000000 -1.000000 -1.000000 -1.000000
-1.000000 -1.000000 -1.000000 -1.000000 -1.000000
-1.000000 -1.000000 -1.000000 -1.000000 -1.000000
-1.000000 -1.000000 -1.000000 -1.000000 -1.000000
-1.000000 -1.000000 -1.000000 -1.000000 -1.000000
-1.000000 -1.000000 -1.000000 -1.000000 -1.000000
-1.000000 -1.000000 -1.000000 0.512110 0.213267
0.303543 0.585991 0.161586 0.336235 0.309890
0.438514 -1.000000 -1.000000 -1.000000 -1.000000
# last three years (1999-2001) are not used - STAR recommendation
# 0.438514 0.176929 0.144952 0.107496 -1.000000

# cv for each index
# cv for NMFS Tiburon/Santa Cruz Lab midwater trawl index
-1.0000 -1.0000 -1.0000 -1.0000 -1.0000
-1.0000 -1.0000 -1.0000 -1.0000 -1.0000
-1.0000 -1.0000 -1.0000 -1.0000 -1.0000
-1.0000 -1.0000 -1.0000 -1.0000 -1.0000
-1.0000 -1.0000 -1.0000 -1.0000 -1.0000
-1.0000 0.4346 0.4897 0.5020 0.2485
0.2869 0.4164 0.4297 0.3197 2.0000
0.2849 0.4880 0.4941 2.0000 0.4214
2.0000 0.5001 0.3657 0.2721 0.3156

# cv for Oregon bottom trawl index
-1 -1 -1 -1 -1
-1 -1 -1 -1 -1
-1 -1 -1 -1 -1
-1 -1 -1 -1 -1

```

```

-1      -1      -1      -1      -1
-1.0  0.2121  0.1875  0.2928  0.2730
0.2897  0.1749  0.1348  0.1275  0.1179
0.1314  0.1128  0.1387  0.1357  0.1502
0.1718  0.1684  -1.0  -1.0  -1.0

# cv for Whiting bycatch index - foreign
-1      -1      -1      -1      -1
-1      -1      -1      -1      -1
-1      -1      -1      -1      -1
-1      -1      -1      0.18894  0.09723
0.07181  0.07846  0.07539  0.07952  0.23103
-1      0.07614  0.08170  0.07524  0.06524
0.09403  -1      -1      -1      -1
-1      -1      -1      -1      -1
-1      -1      -1      -1      -1

# cv for Whiting bycatch index - joint venture (JV)
-1      -1      -1      -1      -1
-1      -1      -1      -1      -1
-1      -1      -1      -1      -1
-1      -1      -1      -1      -1
-1      -1      -1      -1      -1
0.11129  -1      0.14007  0.08222  0.10281
0.08677  0.05863  0.07033  -1      -1
-1      -1      -1      -1      -1
-1      -1      -1      -1      -1

# cv for Whiting bycatch index - domestic
-1      -1      -1      -1      -1
-1      -1      -1      -1      -1
-1      -1      -1      -1      -1
-1      -1      -1      -1      -1
-1      -1      -1      -1      -1
-1      -1      -1      -1      -1
-1      -1      -1      0.11368  0.09850
0.08674  0.05702  0.08717  0.06880  0.06190
0.06534  -1      -1      -1      -1
# 0.06534  0.06557  0.06951  0.07568  -1

# landings

```

```

# VAN-COL Fishery
      -1      -1      -1      -1      -1
      -1      -1      -1    3670     3900
  1693     356      554     701     410
   617     293      454     948    1318
  605.0    966.0   16190.0   21769.8   14793.9
 3213.3   1450.0   1534.4    2551.2   3711.7
 3075.8   3375.2   2231.6   1148.3    935.2
 1702.9   1061.7   1077.5    956.5   1003.7
  539.2    515.5    385.9    297.1     61.2

# OR Midwater Trawl Fishery
-1 -1 -1 -1 -1
-1 -1 -1 -1 -1
-1 -1 -1 -1 -1
-1 -1 -1 -1 -1
-1 -1 -1 -1 -1
  1452.0   3567.6   3185.0   2976.9   4984.8
  4101.6   4870.9   3234.8   1845.5   1149.4
  1754.8   1678.4   1584.7   1851.0   2032.2
   925.9   2237.4   2284.5   957.6    148.1

# OR Bottom Trawl Fishery
-1 -1 -1 -1 -1
-1 -1 -1 -1 -1
-1 -1 -1 -1 -1
-1 -1 -1 -1 -1
-1 -1 -1 -1 -1
   1487.6   1334.2   870.8   1170.6   1169.5
   1126.1   1970.9   2168.0   1940.1   2624.4
   3385.3   2382.2   2278.3   2114.1   2281.3
   1330.7    796.1   18.4     44.5      6.0

# EUR-CON Fishery
      -1      -1      -1      -1      -1
      -1      -1      -1       96     249
    336      21         1       1      13
   207     280        358     412     883
   502.0   2326.0   5666.0   5168.6   11239.4
  4167.7   3464.4   3552.1   2727.3   2716.7
  2148.0   2261.9   2478.3   1355.6   1326.8

```

1347.4	1243.8	2011.9	1556.4	1671.4																
1294.3	900.8	1120.3	495.2	48.2																
# Age compositions from four fisheries																				
# VAN-COL Fishery																				
# number of years of age comps																				
23																				
# years of age comps																				
1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
2001	2002																			
# number of sampled trips																				
18	31	40	25	22	16	27	36	20	30											
41	35	31	36	28	33	27	30	22	29											
21	10	12																		
# male age comps																				
0.000000	0.000000	0.009363	0.021512	0.020342	0.055539	0.095547	0.110577	0.046018	0.029204											
0.011890	0.013060	0.005852	0.004096	0.002341	0.002341	0.001170	0.002926													
0.000444	0.006609	0.024435	0.063737	0.045524	0.024041	0.047744	0.087771	0.067569	0.047083											
0.025763	0.017104	0.011660	0.005331	0.004276	0.003388	0.002887	0.008502													
0.000155	0.008491	0.030499	0.084375	0.030692	0.044964	0.020568	0.021494	0.032650	0.071686											
0.044941	0.034309	0.034855	0.021097	0.014068	0.008806	0.005466	0.016884													
0.000000	0.007569	0.153715	0.113485	0.028422	0.017474	0.014261	0.013099	0.013587	0.018363											
0.020143	0.014780	0.015317	0.008811	0.006339	0.006692	0.005666	0.019890													
0.000000	0.003350	0.053703	0.161029	0.083344	0.033419	0.013850	0.004392	0.005597	0.006802											
0.007517	0.012931	0.012788	0.010684	0.006802	0.007681	0.007681	0.028558													
0.000000	0.008297	0.074816	0.080420	0.124782	0.066450	0.021605	0.009465	0.003556	0.005909											
0.005317	0.006053	0.005460	0.002658	0.005909	0.004724	0.002514	0.028344													
0.000000	0.007004	0.060179	0.173641	0.075174	0.048950	0.014384	0.005971	0.005285	0.005216											
0.003465	0.003122	0.004632	0.006073	0.003224	0.002297	0.001542	0.029481													
0.000000	0.006265	0.024049	0.120012	0.194208	0.046191	0.012870	0.008530	0.002837	0.004189											
0.005540	0.004207	0.003007	0.004055	0.003750	0.002112	0.001504	0.011251													
0.000000	0.000000	0.014864	0.060144	0.136868	0.198865	0.034969	0.013274	0.004554	0.002449											
0.000858	0.002620	0.003135	0.000858	0.000172	0.000515	0.000687	0.014040													
0.000000	0.002563	0.017604	0.093364	0.094971	0.157016	0.087374	0.009204	0.003722	0.001159											
0.000000	0.001282	0.000232	0.000927	0.000232	0.000463	0.001513	0.008465													
0.000000	0.000464	0.025076	0.077340	0.152504	0.068069	0.097414	0.029968	0.011480	0.004530											
0.000978	0.000464	0.000000	0.000464	0.000515	0.000978	0.001029	0.007465													
0.000000	0.001239	0.010045	0.061670	0.114107	0.107255	0.073670	0.043534	0.049590	0.010278											
0.003949	0.002903	0.001665	0.000619	0.004045	0.001142	0.001142	0.018289													

0.000000	0.002617	0.019543	0.030904	0.071547	0.077266	0.081931	0.048736	0.051519	0.029442
0.019792	0.007933	0.004908	0.002700	0.001717	0.000000	0.000900	0.011616		
0.000166	0.000166	0.016699	0.058371	0.051097	0.062834	0.056883	0.035553	0.028608	0.030428
0.022822	0.020172	0.012236	0.006448	0.005291	0.004299	0.001984	0.013891		
0.000000	0.001331	0.010571	0.041365	0.086872	0.057053	0.045358	0.037129	0.028132	0.022809
0.025977	0.016475	0.012951	0.011152	0.004929	0.003598	0.002699	0.017486		
0.000685	0.010197	0.030883	0.056198	0.096140	0.099800	0.063944	0.028600	0.030630	0.018687
0.015002	0.023660	0.010430	0.007430	0.006143	0.007229	0.002457	0.012001		
0.000674	0.010919	0.054020	0.107421	0.101373	0.061162	0.033894	0.020952	0.014655	0.011940
0.007780	0.006875	0.009128	0.003043	0.003832	0.003717	0.002253	0.008454		
0.000000	0.002832	0.036763	0.148924	0.129091	0.049634	0.015218	0.009554	0.006238	0.006812
0.006634	0.008139	0.001327	0.003317	0.002653	0.000663	0.000753	0.003980		
0.000000	0.001088	0.014273	0.042774	0.145688	0.109655	0.039772	0.014534	0.007136	0.008529
0.007703	0.003307	0.002481	0.002481	0.006615	0.000827	0.000000	0.005788		
0.000000	0.001831	0.011040	0.040933	0.080730	0.107025	0.081930	0.041423	0.022625	0.009912
0.009801	0.009154	0.004577	0.005224	0.003662	0.004577	0.001831	0.005224		
0.000000	0.000000	0.004590	0.057898	0.112775	0.071080	0.073505	0.072582	0.038422	0.012587
0.012326	0.005244	0.002098	0.009113	0.006293	0.003147	0.002098	0.005244		
0.000000	0.000000	0.004118	0.051457	0.125630	0.084317	0.061792	0.053584	0.037141	0.039296
0.033078	0.008290	0.016525	0.006218	0.006190	0.006218	0.002073	0.006218		
0.000000	0.001565	0.020347	0.025043	0.056347	0.097041	0.062607	0.051651	0.023478	0.025043
0.010956	0.014087	0.001565	0.001565	0.004696	0.001565	0.001565	0.003130		
# female age comps									
0.000000	0.000000	0.009150	0.018485	0.013561	0.025721	0.087940	0.141807	0.084614	0.062747
0.034713	0.017742	0.021253	0.018513	0.005267	0.007023	0.006437	0.013246		
0.000000	0.007494	0.017214	0.046582	0.043915	0.020375	0.020432	0.062351	0.078447	0.071291
0.037376	0.028320	0.018543	0.010161	0.005388	0.005778	0.005167	0.027296		
0.000311	0.007559	0.018373	0.059590	0.028839	0.041575	0.018823	0.014979	0.014679	0.049251
0.039979	0.040337	0.032736	0.032280	0.016563	0.015107	0.005932	0.037088		
0.000000	0.005567	0.153308	0.113974	0.040329	0.020551	0.009182	0.013519	0.013334	0.016294
0.029275	0.022800	0.021589	0.013149	0.010306	0.006877	0.004523	0.027811		
0.001062	0.001941	0.044000	0.152020	0.075377	0.025555	0.018160	0.005270	0.006496	0.007007
0.011378	0.016832	0.025126	0.023716	0.020100	0.010888	0.013543	0.081403		
0.000000	0.008297	0.070811	0.081461	0.117263	0.057561	0.027515	0.008568	0.006951	0.005317
0.007526	0.005460	0.012394	0.009592	0.010921	0.007221	0.007526	0.099337		
0.000000	0.002024	0.053314	0.177620	0.091239	0.069749	0.020146	0.013248	0.003947	0.006967
0.007652	0.006142	0.008884	0.008402	0.007717	0.009157	0.003497	0.060653		
0.000152	0.004475	0.013899	0.095086	0.224047	0.056797	0.036973	0.025570	0.009424	0.006740
0.003750	0.001960	0.007062	0.007536	0.004833	0.007518	0.004225	0.035374		
0.000000	0.002449	0.007346	0.056150	0.150874	0.206257	0.035267	0.017267	0.012072	0.008204
0.002964	0.000343	0.002620	0.000515	0.000343	0.000858	0.000172	0.007426		

0.000000	0.002563	0.007104	0.075898	0.092900	0.183621	0.104392	0.008972	0.009790	0.005822
0.000695	0.001050	0.001050	0.001513	0.000000	0.000927	0.003613	0.020000		
0.000000	0.001442	0.027599	0.062046	0.115589	0.077798	0.119346	0.059062	0.012203	0.005508
0.002522	0.002935	0.000464	0.001029	0.002471	0.000978	0.000927	0.029343		
0.000000	0.000000	0.003852	0.054295	0.084317	0.099027	0.065619	0.056732	0.053596	0.010801
0.009329	0.004665	0.004142	0.002477	0.000619	0.003000	0.002381	0.040005		
0.000000	0.003025	0.023468	0.025345	0.055355	0.091344	0.081860	0.056669	0.069345	0.045876
0.029850	0.011693	0.007850	0.004417	0.000900	0.003600	0.002125	0.024208		
0.000000	0.000992	0.008103	0.059030	0.037868	0.067636	0.070119	0.054907	0.049947	0.084023
0.047961	0.029274	0.015218	0.008769	0.002978	0.004465	0.001986	0.028777		
0.003524	0.002662	0.013345	0.046763	0.073830	0.067831	0.043766	0.054391	0.041440	0.043277
0.052123	0.034749	0.024646	0.016044	0.012951	0.007591	0.004423	0.030757		
0.000685	0.009311	0.032027	0.050314	0.077627	0.081629	0.055487	0.036799	0.023485	0.027229
0.017200	0.020543	0.009686	0.006887	0.010773	0.004772	0.001571	0.013857		
0.000000	0.001579	0.066768	0.107961	0.105186	0.062608	0.054288	0.024226	0.015657	0.019161
0.015329	0.012845	0.019161	0.004622	0.003948	0.002253	0.002253	0.020066		
0.000000	0.000663	0.028713	0.167230	0.141834	0.052823	0.033179	0.023574	0.016851	0.018000
0.017336	0.010039	0.007297	0.010614	0.005396	0.001990	0.002653	0.029277		
0.000000	0.001088	0.012053	0.047736	0.165170	0.153428	0.046648	0.020322	0.022758	0.023063
0.019540	0.021454	0.014273	0.004395	0.011271	0.004656	0.002481	0.017014		
0.000000	0.001239	0.012224	0.046000	0.066841	0.126525	0.104824	0.052952	0.032861	0.022838
0.015081	0.013195	0.014378	0.008562	0.005816	0.011308	0.005492	0.018364		
0.000000	0.000000	0.001770	0.053434	0.088249	0.097235	0.076904	0.069235	0.046092	0.021372
0.009834	0.009440	0.006293	0.006293	0.006293	0.009440	0.002098	0.007015		
0.000000	0.000000	0.002073	0.024679	0.053475	0.090370	0.057511	0.014371	0.031033	0.024843
0.047668	0.035205	0.016580	0.018653	0.004145	0.006190	0.008290	0.022770		
0.000000	0.001565	0.023478	0.025043	0.026608	0.101737	0.097041	0.042260	0.043825	0.032869
0.028173	0.025043	0.021913	0.009391	0.001565	0.010956	0.004696	0.020347		

```

# OR Midwater Trawl Fishery
# number of years of age comps
19
# years of age comps
1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002
#sampled trips
33   51   56   62   38   61   60   60   29   50
22   12   14   21    9   11   34   23   15
# male age comps
0.000000 0.001249 0.016659 0.187552 0.113736 0.008303 0.018400 0.006489 0.008219 0.007183
0.014697 0.021419 0.001752 0.007367 0.003349 0.001785 0.000757 0.011289

```

0.000000	0.002236	0.061929	0.066605	0.224736	0.060317	0.007770	0.005961	0.003059	0.000000
0.001733	0.005233	0.014244	0.002656	0.002328	0.000000	0.000000	0.010138		
0.000000	0.000000	0.005472	0.104226	0.073530	0.195109	0.059656	0.004993	0.005095	0.003740
0.000000	0.000447	0.001136	0.012770	0.003982	0.002755	0.001405	0.007587		
0.000000	0.000000	0.016510	0.125854	0.221917	0.070980	0.037336	0.018807	0.002107	0.002889
0.002529	0.000356	0.000199	0.001560	0.003057	0.000000	0.001158	0.002806		
0.000484	0.001185	0.014211	0.075913	0.238582	0.131816	0.032351	0.021121	0.008094	0.000000
0.000000	0.000460	0.000889	0.000000	0.002745	0.002132	0.000000	0.003647		
0.000000	0.004102	0.016060	0.047419	0.116290	0.188631	0.070785	0.012981	0.014107	0.002258
0.000247	0.000087	0.000497	0.000672	0.002144	0.002143	0.003487	0.005763		
0.000000	0.003321	0.028176	0.029987	0.057839	0.100289	0.132836	0.067550	0.033021	0.015717
0.007527	0.003601	0.000000	0.000974	0.000000	0.001817	0.000000	0.004279		
0.000000	0.000000	0.007709	0.066309	0.100305	0.105528	0.064610	0.088096	0.038765	0.009553
0.011144	0.003093	0.002417	0.001644	0.001308	0.000000	0.000542	0.009658		
0.000000	0.000000	0.035945	0.039720	0.087052	0.083027	0.080416	0.041211	0.085709	0.030049
0.021923	0.013500	0.002018	0.004160	0.000000	0.000000	0.001193	0.013024		
0.000000	0.000000	0.016302	0.070921	0.055203	0.081487	0.049299	0.038564	0.034325	0.059574
0.026062	0.017941	0.014803	0.006404	0.000000	0.003025	0.001142	0.010385		
0.000060	0.001656	0.008803	0.075885	0.155556	0.079729	0.046850	0.041458	0.011685	0.019825
0.031305	0.000000	0.001604	0.005385	0.000000	0.000000	0.000000	0.009487		
0.000000	0.004118	0.016270	0.020655	0.131529	0.101559	0.050600	0.047015	0.033035	0.022577
0.030138	0.007105	0.000000	0.000000	0.000000	0.005901	0.000000	0.000875		
0.000000	0.008826	0.074117	0.094208	0.072464	0.067619	0.049638	0.034572	0.013109	0.007989
0.023724	0.008520	0.017650	0.008086	0.002783	0.000000	0.004642	0.004642		
0.000000	0.002806	0.033832	0.259303	0.124430	0.041638	0.024120	0.026377	0.013285	0.011185
0.006524	0.000000	0.010993	0.012657	0.000000	0.000000	0.000000	0.002096		
0.000000	0.000000	0.015530	0.098950	0.199935	0.091861	0.057067	0.013497	0.027997	0.012242
0.001408	0.004779	0.000000	0.000000	0.010976	0.000000	0.000000	0.000000		
0.000000	0.000000	0.016491	0.032183	0.108712	0.188452	0.091741	0.023373	0.004784	0.003869
0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000		
0.000000	0.000000	0.004870	0.033511	0.071985	0.086101	0.115372	0.089305	0.048252	0.032821
0.004816	0.007448	0.008363	0.001826	0.000484	0.000000	0.000000	0.000000		
0.000000	0.000000	0.001276	0.018646	0.099895	0.100433	0.122495	0.062026	0.049961	0.041285
0.016040	0.005449	0.000917	0.002853	0.001224	0.001309	0.003946	0.003427		
0.000000	0.004930	0.009861	0.045050	0.075314	0.187089	0.173179	0.053133	0.005955	0.010136
0.011321	0.006201	0.000000	0.015429	0.002614	0.000000	0.007491	0.002614		
# female age comps									
0.000000	0.001430	0.018876	0.168858	0.180568	0.014028	0.027547	0.005962	0.006322	0.003556
0.026679	0.057693	0.015561	0.008459	0.006485	0.005497	0.005571	0.016705		
0.000000	0.000000	0.045566	0.066237	0.254100	0.090627	0.009295	0.013232	0.009939	0.000000
0.001286	0.007335	0.018569	0.002860	0.001582	0.001291	0.002024	0.007111		

0.000000	0.000000	0.009637	0.136513	0.082163	0.168330	0.067111	0.004429	0.010694	0.004409
0.000000	0.000378	0.003912	0.016306	0.001360	0.002328	0.001568	0.008958		
0.000000	0.001091	0.014721	0.115256	0.203142	0.080172	0.040652	0.021862	0.001310	0.004031
0.001509	0.000112	0.000776	0.001381	0.002411	0.001268	0.000368	0.001872		
0.001029	0.004892	0.013675	0.075696	0.192004	0.101985	0.026823	0.017744	0.009244	0.004444
0.004669	0.000000	0.001092	0.000000	0.001435	0.004233	0.002816	0.004590		
0.000000	0.003358	0.022650	0.033519	0.075956	0.195248	0.087347	0.031686	0.015902	0.015279
0.009010	0.001810	0.000000	0.000736	0.000000	0.001558	0.006418	0.011850		
0.000000	0.000000	0.018465	0.032629	0.054334	0.076913	0.146584	0.105843	0.038064	0.021354
0.009218	0.002280	0.001955	0.000588	0.000855	0.000000	0.000000	0.003982		
0.000000	0.000000	0.010833	0.062981	0.095774	0.061101	0.068012	0.097786	0.042921	0.013368
0.009791	0.004393	0.003129	0.000766	0.000475	0.000475	0.002365	0.015151		
0.000000	0.000000	0.023080	0.029597	0.070216	0.075317	0.042247	0.063636	0.088798	0.031001
0.015295	0.006497	0.001193	0.001984	0.002030	0.002224	0.000000	0.007939		
0.000000	0.000619	0.010235	0.067949	0.036055	0.079940	0.065430	0.035775	0.045776	0.067009
0.033835	0.023914	0.020267	0.010147	0.004298	0.005024	0.001773	0.006514		
0.000000	0.000060	0.008346	0.048716	0.157869	0.064175	0.055961	0.041445	0.034903	0.024695
0.028568	0.014965	0.020718	0.004541	0.000000	0.000000	0.002325	0.003423		
0.000000	0.005120	0.001749	0.023846	0.051270	0.087778	0.092110	0.056424	0.041653	0.040139
0.034589	0.049286	0.013028	0.008287	0.015797	0.000000	0.000000	0.007545		
0.000000	0.007283	0.070601	0.056463	0.077147	0.081687	0.050333	0.023961	0.038670	0.014234
0.017401	0.021785	0.017618	0.005426	0.000000	0.000000	0.000000	0.024802		
0.000000	0.002383	0.012543	0.175490	0.080717	0.036773	0.032677	0.015670	0.011586	0.010607
0.011692	0.012565	0.005771	0.016006	0.000000	0.002109	0.000000	0.004163		
0.000000	0.000000	0.006109	0.048113	0.185918	0.077374	0.040626	0.030824	0.030518	0.012242
0.013650	0.014337	0.000000	0.000000	0.006044	0.000000	0.000000	0.000000		
0.000000	0.000000	0.017880	0.032733	0.079706	0.200105	0.096218	0.042890	0.021087	0.008190
0.011668	0.007799	0.000000	0.007859	0.004260	0.000000	0.000000	0.000000		
0.000000	0.000000	0.009708	0.033562	0.060751	0.104919	0.079882	0.089598	0.056252	0.023820
0.014228	0.003328	0.005488	0.001495	0.003434	0.000000	0.004947	0.003434		
0.000000	0.000000	0.000000	0.013107	0.068597	0.067549	0.072160	0.068760	0.048729	0.061027
0.016128	0.008625	0.007554	0.007749	0.013160	0.007822	0.005252	0.002596		
0.000000	0.004930	0.004930	0.014738	0.030937	0.087590	0.092853	0.100610	0.029888	0.003936
0.008815	0.002614	0.000000	0.000000	0.002614	0.000000	0.002614	0.002614		

# OR Bottom Trawl Fishery

# number of years of age comps

16

# years of age comps

1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999

# number of trips sampled

26 21 22 26 32 43 49 77 82 61 63 43 27 40 30 26

```

# male age comps
  0.000000  0.002256  0.034350  0.158286  0.114997  0.018091  0.017290  0.003513  0.003880  0.002198
  0.020528  0.014953  0.010928  0.008799  0.006910  0.003303  0.001141  0.010381
  0.000000  0.003438  0.049274  0.096921  0.194764  0.048663  0.002711  0.005276  0.001901  0.000000
  0.001433  0.003908  0.026266  0.000000  0.007354  0.001080  0.000239  0.006845
  0.000000  0.002454  0.013898  0.200133  0.081381  0.084669  0.058429  0.002879  0.018189  0.005390
  0.002106  0.000000  0.001446  0.017614  0.002031  0.001018  0.002843  0.015690
  0.000000  0.000000  0.011376  0.110773  0.203604  0.071707  0.039611  0.016169  0.002925  0.002485
  0.007011  0.000000  0.000000  0.006076  0.005411  0.002037  0.000000  0.007864
  0.001883  0.011101  0.016738  0.079601  0.207562  0.102228  0.021546  0.011411  0.007454  0.003072
  0.000493  0.000111  0.001149  0.000178  0.002458  0.003537  0.001278  0.006354
  0.000000  0.009287  0.024672  0.051324  0.094312  0.176468  0.063539  0.026553  0.014418  0.008453
  0.000000  0.005166  0.000206  0.000021  0.001340  0.000702  0.006404  0.006529
  0.000000  0.003583  0.046610  0.044816  0.055997  0.068434  0.115960  0.057955  0.020822  0.019537
  0.009585  0.004483  0.001307  0.002656  0.000000  0.000000  0.000000  0.011648
  0.000000  0.000153  0.004361  0.066335  0.099842  0.071706  0.042144  0.077733  0.037488  0.009870
  0.012275  0.003344  0.001112  0.003725  0.000190  0.000000  0.001242  0.010660
  0.000000  0.000210  0.017104  0.021507  0.083738  0.072799  0.059036  0.034356  0.048167  0.017539
  0.028795  0.015892  0.004209  0.004150  0.005980  0.001566  0.002672  0.017018
  0.000000  0.000000  0.005855  0.035253  0.034549  0.088243  0.091091  0.046518  0.033369  0.054327
  0.034564  0.022812  0.013524  0.004287  0.002129  0.003937  0.000464  0.016873
  0.000000  0.003066  0.014275  0.056658  0.107092  0.068690  0.042280  0.016704  0.020763  0.028991
  0.023737  0.008231  0.006195  0.004521  0.008745  0.002407  0.000000  0.010728
  0.000000  0.002979  0.033648  0.108932  0.073740  0.135371  0.039055  0.044337  0.020910  0.017927
  0.007067  0.012256  0.004705  0.005004  0.005162  0.000343  0.000000  0.002308
  0.000000  0.001546  0.078624  0.082232  0.058865  0.058378  0.022296  0.017354  0.016860  0.020354
  0.015502  0.002110  0.016646  0.004691  0.001983  0.010887  0.000918  0.007283
  0.000000  0.006259  0.044095  0.229768  0.118118  0.047116  0.031456  0.020552  0.009284  0.017502
  0.007340  0.006334  0.000686  0.005679  0.001947  0.000212  0.000000  0.003644
  0.000000  0.000000  0.008048  0.051295  0.182533  0.115763  0.034581  0.021837  0.017118  0.020333
  0.006225  0.009028  0.000040  0.001808  0.007220  0.000000  0.003032  0.007934
  0.000000  0.004410  0.028185  0.065780  0.117624  0.177422  0.072072  0.027160  0.008664  0.000260
  0.000000  0.007039  0.001389  0.000369  0.000145  0.000260  0.006664  0.002549
# female age comps
  0.000000  0.000000  0.032939  0.135291  0.187894  0.031169  0.017811  0.012851  0.008093  0.005203
  0.014013  0.033771  0.016960  0.009134  0.005225  0.005921  0.002984  0.048939
  0.000607  0.000000  0.023198  0.061654  0.199215  0.121213  0.015786  0.006508  0.006886  0.000105
  0.001217  0.025712  0.037555  0.005527  0.006142  0.003854  0.004280  0.030468
  0.000000  0.001065  0.024774  0.106338  0.062243  0.095637  0.067655  0.006901  0.017638  0.013061
  0.000257  0.000000  0.003720  0.043907  0.009912  0.006982  0.004653  0.025086

```

0.000000	0.001612	0.010471	0.118577	0.167351	0.059526	0.050732	0.029897	0.003664	0.003772
0.001553	0.003126	0.000279	0.004793	0.016950	0.013894	0.003419	0.023334		
0.009667	0.014422	0.009462	0.077392	0.171968	0.102983	0.040671	0.026837	0.015251	0.010129
0.004653	0.006024	0.000836	0.002500	0.006400	0.010212	0.002776	0.009663		
0.000000	0.001306	0.027152	0.028407	0.067983	0.145676	0.089559	0.038399	0.040758	0.015682
0.005735	0.004099	0.004103	0.004168	0.005656	0.003995	0.010155	0.017774		
0.000000	0.000346	0.045983	0.035820	0.037131	0.067841	0.137383	0.107247	0.036003	0.017221
0.008657	0.004878	0.006605	0.002256	0.002494	0.001175	0.001334	0.024232		
0.000000	0.000288	0.007202	0.054594	0.060310	0.065256	0.074390	0.108814	0.058457	0.034054
0.034290	0.007292	0.004797	0.004545	0.002187	0.000548	0.003433	0.037360		
0.000000	0.000000	0.009753	0.008144	0.081541	0.088796	0.068771	0.057565	0.089954	0.047986
0.031772	0.019963	0.014438	0.004916	0.006446	0.001441	0.002506	0.031269		
0.000000	0.000000	0.000299	0.025279	0.025262	0.075644	0.073311	0.044332	0.040169	0.066328
0.042838	0.028744	0.017316	0.020636	0.005716	0.008841	0.005620	0.031867		
0.000000	0.002217	0.008820	0.042980	0.100462	0.063347	0.056897	0.063275	0.046037	0.026311
0.064738	0.028538	0.019849	0.012475	0.012450	0.006566	0.006008	0.015944		
0.000000	0.004849	0.012570	0.037066	0.109137	0.084212	0.050834	0.038905	0.045410	0.025559
0.017455	0.024881	0.003947	0.002003	0.013073	0.001605	0.000000	0.014750		
0.000097	0.007272	0.076010	0.101629	0.082023	0.086098	0.050735	0.028263	0.040649	0.032268
0.008394	0.004318	0.039893	0.000000	0.001771	0.010131	0.002891	0.011030		
0.000000	0.008041	0.030840	0.103883	0.094444	0.030399	0.046719	0.030626	0.019097	0.014813
0.008142	0.013020	0.009741	0.016087	0.004702	0.000592	0.005036	0.013827		
0.000000	0.000000	0.011607	0.047322	0.140566	0.110448	0.053762	0.024241	0.030259	0.017303
0.025682	0.013208	0.015729	0.002847	0.008011	0.001866	0.001373	0.008983		
0.000000	0.000000	0.023360	0.057678	0.067752	0.146783	0.062621	0.042079	0.039373	0.008637
0.011882	0.006203	0.007617	0.002111	0.000000	0.001389	0.001141	0.001385		

```

# EUR-CON Fishery
# number of years of age comps
23
# years of age comps
1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
2001 2002
# number of trips sampled
70    100   126   167   137   118   102   101   74    72
85    54    33    20    25    11    33    52    31    31
14     7    10
# male age comps
0.000000 0.000000 0.001101 0.020452 0.012065 0.006539 0.056207 0.040580 0.069361 0.040111
0.059960 0.010733 0.036832 0.016148 0.003139 0.002890 0.005833 0.012366

```

0.000000	0.007525	0.003359	0.026620	0.027215	0.023253	0.017584	0.063422	0.086313	0.059538
0.032106	0.011993	0.008724	0.014630	0.002378	0.002646	0.009223	0.001450		
0.000000	0.000022	0.035921	0.004753	0.034537	0.037436	0.031183	0.014870	0.043597	0.108641
0.034402	0.040403	0.024284	0.010358	0.013375	0.013230	0.006330	0.024984		
0.000000	0.000023	0.019684	0.134354	0.027445	0.031902	0.014049	0.005503	0.006724	0.007225
0.015465	0.017042	0.010764	0.010665	0.003746	0.024730	0.001883	0.041946		
0.000000	0.000000	0.022177	0.136865	0.144882	0.027534	0.035797	0.014452	0.013815	0.001723
0.010158	0.030363	0.014161	0.004130	0.005053	0.003807	0.004250	0.029903		
0.000000	0.000227	0.008622	0.062244	0.162794	0.144850	0.012740	0.025432	0.011326	0.002269
0.002575	0.010161	0.021668	0.002268	0.004800	0.003061	0.003256	0.026758		
0.000000	0.002672	0.041614	0.045810	0.082096	0.123917	0.129130	0.013757	0.021789	0.017389
0.001018	0.000893	0.008456	0.029102	0.005577	0.008659	0.003709	0.037843		
0.001179	0.000152	0.054998	0.114196	0.043553	0.059667	0.090873	0.112021	0.019943	0.029954
0.021102	0.002845	0.000000	0.018666	0.014648	0.002809	0.011094	0.025925		
0.000044	0.035380	0.000332	0.065560	0.060575	0.090206	0.060701	0.051129	0.034404	0.014184
0.008844	0.007881	0.003430	0.003586	0.006491	0.016135	0.001500	0.016273		
0.000000	0.004922	0.108813	0.072992	0.077959	0.119011	0.046296	0.050071	0.019741	0.011676
0.020419	0.015728	0.008211	0.000000	0.000338	0.007197	0.005816	0.008951		
0.000198	0.000005	0.045231	0.116161	0.029490	0.046574	0.037731	0.056019	0.029941	0.024640
0.016278	0.022979	0.019002	0.014258	0.003722	0.002474	0.008377	0.005882		
0.000000	0.002436	0.015488	0.119032	0.119577	0.049449	0.037842	0.065086	0.022067	0.016393
0.020120	0.012377	0.001613	0.003541	0.003664	0.002594	0.002776	0.017436		
0.000000	0.001110	0.011299	0.018839	0.138318	0.094889	0.037718	0.016739	0.044004	0.027766
0.021343	0.019358	0.011102	0.005458	0.016019	0.001048	0.001845	0.023196		
0.000000	0.000000	0.084585	0.163306	0.095533	0.077734	0.009972	0.001732	0.009303	0.006881
0.010719	0.000920	0.020993	0.004707	0.001861	0.004059	0.000628	0.032682		
0.001882	0.003574	0.007108	0.070279	0.148029	0.109588	0.064736	0.021235	0.023515	0.006816
0.007885	0.004744	0.006368	0.008510	0.000880	0.004805	0.000299	0.005238		
0.000000	0.033490	0.039138	0.033789	0.056445	0.196870	0.044622	0.066035	0.057784	0.003157
0.028233	0.006769	0.020519	0.001013	0.004425	0.008088	0.000051	0.003038		
0.003544	0.005653	0.046056	0.045052	0.066636	0.114331	0.117781	0.033128	0.026658	0.018426
0.015394	0.003008	0.024927	0.006853	0.002391	0.002031	0.008824	0.013330		
0.000000	0.001634	0.008364	0.108288	0.040725	0.051077	0.052119	0.048417	0.049544	0.035874
0.026884	0.022934	0.012512	0.005025	0.004030	0.012426	0.006304	0.012199		
0.000000	0.0007713	0.081754	0.060620	0.092682	0.068982	0.053847	0.020544	0.045442	0.025031
0.018261	0.017733	0.005455	0.007462	0.009450	0.000313	0.000000	0.012849		
0.000792	0.001303	0.018542	0.072137	0.059251	0.100602	0.069004	0.051386	0.026777	0.022079
0.029557	0.016272	0.006032	0.005804	0.005619	0.012011	0.004983	0.031026		
0.000000	0.000000	0.003526	0.043905	0.060881	0.116213	0.055216	0.044377	0.027284	0.028240
0.009386	0.000345	0.002868	0.003058	0.008237	0.002356	0.002153	0.001940		

0.000000	0.000172	0.000000	0.010409	0.072637	0.012072	0.064488	0.092402	0.034594	0.039625
0.032375	0.030079	0.041966	0.021130	0.004095	0.003259	0.000000	0.006689		
0.000000	0.009841	0.001600	0.000640	0.013962	0.030804	0.042245	0.101372	0.027563	0.019642
0.100732	0.029764	0.058887	0.000400	0.029524	0.000000	0.034644	0.040165		
# female age comps									
0.000000	0.000000	0.001807	0.004663	0.003000	0.001639	0.091261	0.161763	0.074516	0.069882
0.075663	0.044014	0.012274	0.005410	0.023290	0.007119	0.003319	0.026065		
0.000000	0.005785	0.001472	0.019295	0.026989	0.013633	0.006454	0.048933	0.130691	0.095476
0.045230	0.058596	0.044370	0.041559	0.019433	0.007923	0.010682	0.025498		
0.000000	0.000176	0.020384	0.011435	0.025904	0.021826	0.026403	0.009879	0.028476	0.093480
0.052245	0.041606	0.036602	0.030329	0.026629	0.036041	0.016737	0.043521		
0.000000	0.008585	0.067236	0.183436	0.044969	0.047447	0.013754	0.009714	0.003219	0.006921
0.031805	0.022378	0.013769	0.026297	0.017827	0.013855	0.023165	0.092470		
0.000000	0.000000	0.025400	0.124378	0.113089	0.026752	0.029462	0.011598	0.007136	0.003342
0.019946	0.045211	0.009560	0.010595	0.006944	0.007132	0.010240	0.050144		
0.000000	0.000151	0.001560	0.038649	0.152562	0.144097	0.019940	0.038756	0.006481	0.001962
0.002983	0.010131	0.022748	0.001717	0.006368	0.006675	0.009452	0.030716		
0.000000	0.001094	0.032346	0.027042	0.073440	0.081848	0.100382	0.007086	0.021131	0.009354
0.004758	0.001774	0.001549	0.027713	0.003342	0.003768	0.003633	0.026310		
0.001179	0.000098	0.047208	0.095361	0.021292	0.050757	0.050894	0.055412	0.011451	0.010172
0.004021	0.002340	0.000793	0.004487	0.002818	0.005991	0.000865	0.011236		
0.000140	0.085843	0.037469	0.075957	0.071866	0.055259	0.032502	0.037143	0.021209	0.003896
0.014219	0.019743	0.004235	0.006851	0.003575	0.006002	0.008808	0.038628		
0.000000	0.003411	0.081763	0.042605	0.042417	0.081496	0.053703	0.037811	0.021243	0.009702
0.007578	0.003805	0.006337	0.005543	0.000000	0.000650	0.001295	0.022498		
0.000005	0.003187	0.050819	0.108911	0.056288	0.036766	0.088722	0.070834	0.037058	0.024351
0.009827	0.008493	0.006215	0.001197	0.003355	0.001205	0.002170	0.011633		
0.000226	0.007123	0.008134	0.112901	0.128173	0.060714	0.030229	0.033110	0.023240	0.016982
0.013082	0.010959	0.008170	0.008172	0.006845	0.000731	0.001688	0.018028		
0.000000	0.000232	0.015337	0.031121	0.108172	0.086481	0.039057	0.030308	0.037403	0.026187
0.025779	0.043862	0.015023	0.000488	0.001450	0.001391	0.005892	0.041767		
0.000000	0.004208	0.033435	0.135163	0.123584	0.096949	0.036693	0.004437	0.001141	0.009519
0.007614	0.001330	0.000782	0.000971	0.001365	0.005160	0.005189	0.006846		
0.001882	0.001724	0.022476	0.067422	0.161344	0.066366	0.050772	0.019637	0.025889	0.016917
0.015069	0.006851	0.009371	0.007548	0.006287	0.000228	0.001724	0.023001		
0.000000	0.008129	0.009087	0.015496	0.050148	0.136555	0.049764	0.068335	0.023258	0.004577
0.007731	0.002032	0.005057	0.007653	0.000000	0.007704	0.000000	0.001013		
0.005316	0.007498	0.039650	0.042831	0.041834	0.081434	0.058032	0.049604	0.037617	0.029501
0.010778	0.009947	0.012242	0.002580	0.001429	0.007214	0.004894	0.003579		
0.000076	0.001013	0.007263	0.082973	0.037783	0.055790	0.052979	0.041542	0.064828	0.047760
0.030352	0.020260	0.004756	0.021095	0.006388	0.006955	0.005416	0.014417		

```

0.000000 0.001686 0.053952 0.029427 0.075695 0.029682 0.045987 0.045308 0.052631 0.060361
0.028177 0.007907 0.009615 0.006146 0.006612 0.001982 0.003342 0.013353
0.000193 0.001612 0.010229 0.073635 0.045978 0.093642 0.041606 0.047047 0.038160 0.022148
0.021134 0.015287 0.014316 0.014162 0.003980 0.008607 0.001844 0.013246
0.000000 0.000000 0.006821 0.032812 0.098604 0.073335 0.075038 0.056790 0.039492 0.027416
0.059198 0.032557 0.032994 0.021127 0.002356 0.000562 0.023627 0.007284
0.000000 0.000000 0.000000 0.008190 0.060086 0.098599 0.036981 0.065238 0.063643 0.032407
0.037632 0.022603 0.020863 0.000945 0.012646 0.022527 0.033776 0.017871
0.000000 0.010241 0.001600 0.000800 0.030164 0.012522 0.040965 0.111813 0.052606 0.071569
0.001280 0.034244 0.032244 0.034884 0.005921 0.005521 0.000000 0.011841
# Ageing Error Matrix
# row is true age, column is observed age (column sums to 1)
0.7620 0.1217 0.0006 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000
0.2315 0.7560 0.1244 0.0006 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000
0.0065 0.1217 0.7500 0.1274 0.0007 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000
0.0000 0.0005 0.1244 0.7440 0.1303 0.0008 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000
0.0000 0.0000 0.0006 0.1274 0.7380 0.1332 0.0009 0.0000 0.0000 0.0000
0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000
0.0000 0.0000 0.0000 0.0006 0.1303 0.7320 0.1361 0.0010 0.0000 0.0000
0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000
0.0000 0.0000 0.0000 0.0000 0.0007 0.1332 0.7260 0.1390 0.0011 0.0000
0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000
0.0000 0.0000 0.0000 0.0000 0.0000 0.0008 0.1361 0.7200 0.1419 0.0000
0.0012 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000
0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0009 0.1390 0.7140 0.0000
0.1448 0.0014 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000

```

0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0010	0.1419
0.7080	0.1476	0.0015	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000										
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0011	
0.1448	0.7020	0.1505	0.0017	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
0.0000										
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0012	0.1476	0.6960	0.1533	0.0019	0.0000	0.0000	0.0000	0.0000	0.0000	
0.0000										
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0014	0.1505	0.6900	0.1561	0.0020	0.0000	0.0000	0.0000	0.0000	
0.0000										
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0015	0.1533	0.6840	0.1590	0.0023	0.0000	0.0000	0.0000	
0.0000										
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0017	0.1561	0.6780	0.1617	0.0026	0.0000	0.0000	
0.0007										
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0019	0.1590	0.6720	0.1657	0.0000	0.0000	
0.0313										
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0020	0.1617	0.6660	0.0000	
0.3080										
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0023	0.1657	
0.6600										

```

# Parameter for rebuilding data output
# end year for B0 calculation
1982
# start year for recruitment resampling
1986
# number of recent years for weighting fecundity, weight, and selectivity
5
# recruitment overriding for rebuilding analysis (1 = yes, 0 = no)
1

```